Energy and Electricity Generation

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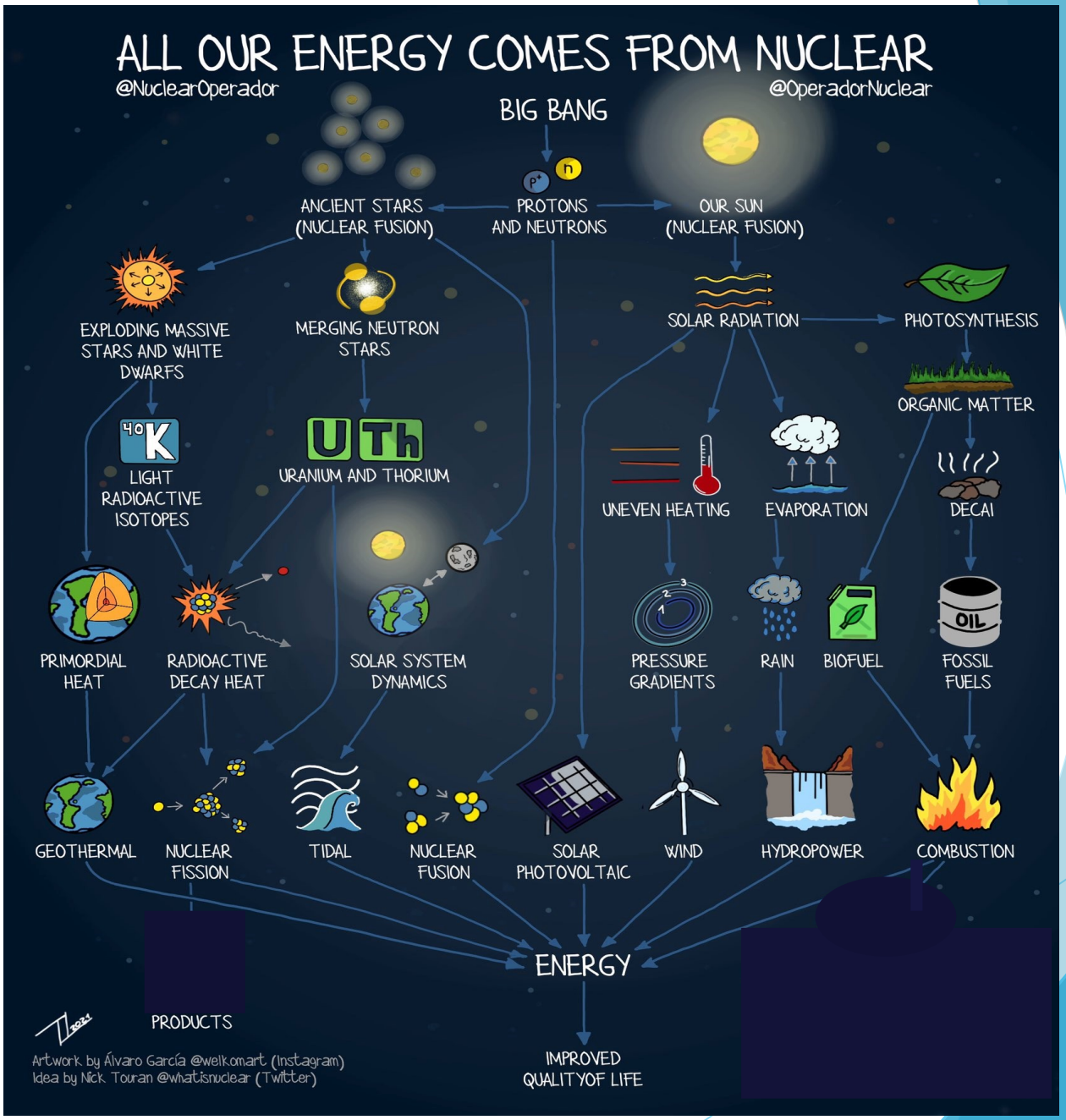
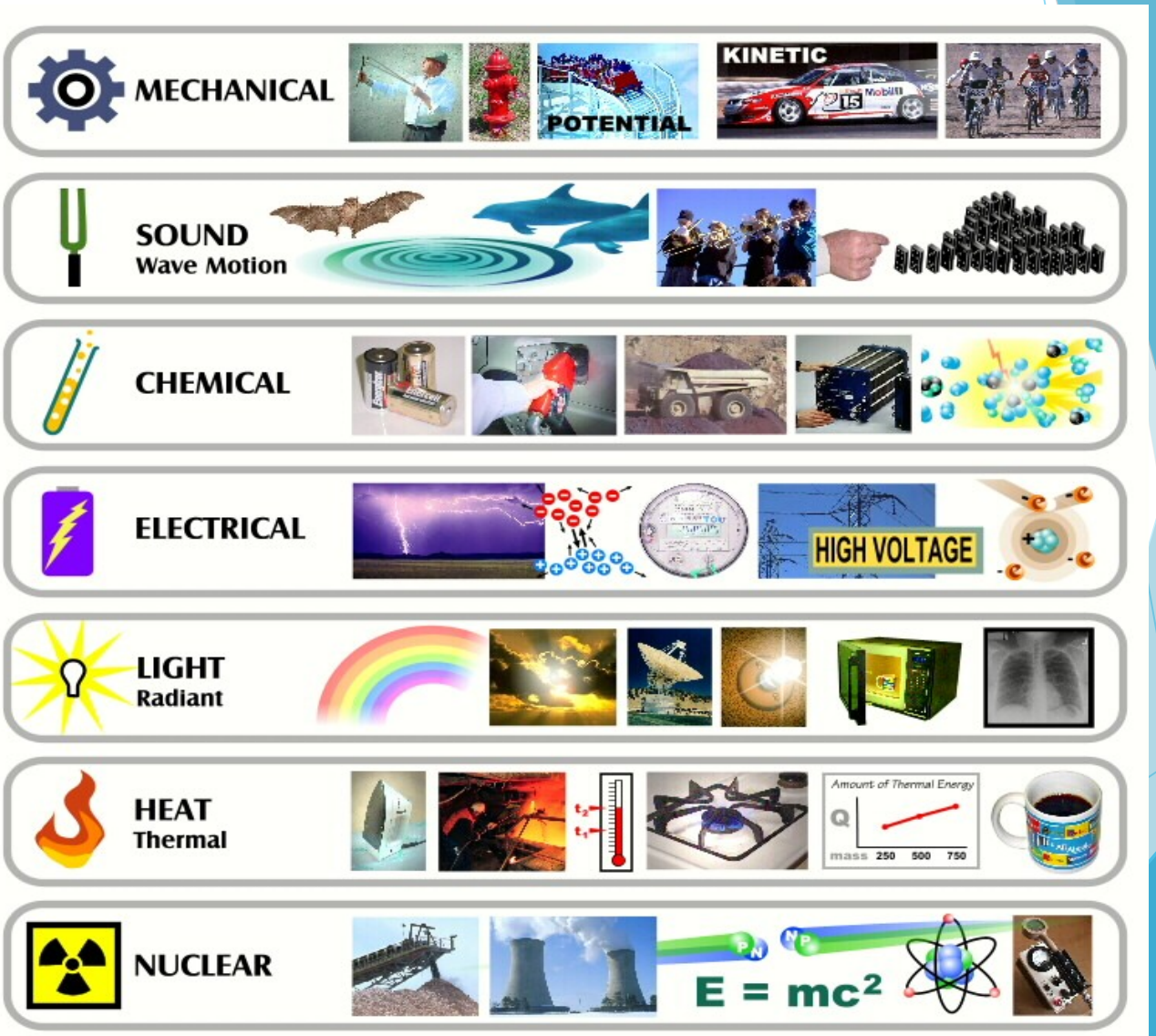
Energy Defined

- Energy – not physical quantity that can be measured directly, but property of things giving them ability to perform work (can be expressed in variety of units)
- Conservation of energy – energy cannot be created or destroyed, only converted from one form to another; one of most important laws of physics
- No work of any kind can be performed without expenditure of energy


ALL OUR ENERGY COMES FROM NUCLEAR
@NuclearOperador
@OperadorNuclear
BIG BANG
ANCIENT STARS (NUCLEAR FUSION)
PROTONS AND NEUTRONS
OUR SUN (NUCLEAR FUSION)
EXPLODING MASSIVE STARS AND WHITE DWARFS
MERGING NEUTRON STARS
SOLAR RADIATION
PHOTOSYNTHESIS
ORGANIC MATTER
LIGHT RADIOACTIVE ISOTOPES
URANIUM AND THORIUM
UNEVEN HEATING
EVAPORATION
DECAI
PRIMORDIAL HEAT
RADIOACTIVE DECAY HEAT
SOLAR SYSTEM DYNAMICS
PRESSURE GRADIENTS
RAIN
BIOFUEL
FOSSIL FUELS
GEOTHERMAL
NUCLEAR FISSION
TIDAL
NUCLEAR FUSION
SOLAR PHOTOVOLTAIC
WIND
HYDROPOWER
COMBUSTION
ENERGY
PRODUCTS
IMPROVED QUALITYOF LIFE
Artwork by Álvaro García @welk.omart (Instagram)
Idea by Nick Touran @whatisnuclear (Twitter)

Energy Forms



Energy Facts

- Not all forms of energy can be converted completely into work, even under ideal conditions; some energy dissipated as waste heat
- Only 100% efficient energy conversion processes are direct conversion to heat
- Available energy – portion of energy that can theoretically be converted into work
- Useful energy – portion of energy actually converted into work
- Energy conversion efficiency – ratio of useful energy to available energy

A Very Brief History of Energy*

Era	Pre-Industrial Revolution	Industrial Revolution (roughly 1750-1840)	Post-Industrial Revolution
Energy Resource	Wind, Sun, Water, Animals, Humans	Fossil Fuels	Uranium, Thorium
Energy Density (kWh per kg)	< 0.001†	< 15	> 20 million
Resource Benefits	Familiar	Mechanization of labor; major industrial development; electricity generation; vastly improved world economies; increased human lifespan	Reliable 24/7 electricity generation; safe, compact, essentially inexhaustible energy resource
Resource Shortcomings	Intermittent availability; very localized domains of use	Environmentally damaging waste; finite resources	Moderate waste impact on environment; public fear of radiation due to poor education, misinformation

* Adapted from Wade Allison, *Nature Energy and Society: A scientific study of the options facing civilization today*, March 2020; wade.allison@physics.ox.ac.uk

† One hour's work from 800 kg draft horse is about 0.0009 kWh/kg

Pre-Industrial Revolution Energy Resources

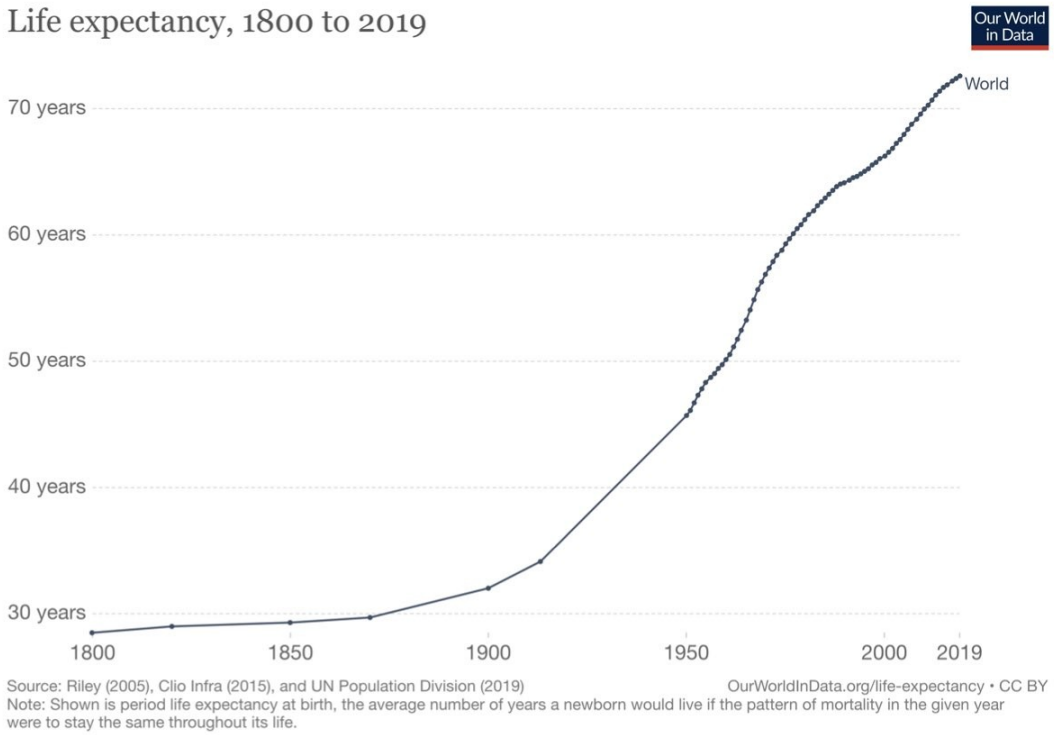
- Sun
  - Source of biofuels such as wood for providing heat
  - Source of nutrition (plant life) for animals used to perform work or provide transportation (e.g., oxen and horses)
- Wind
  - Source of motive power for boats and ocean-going ships
  - Energy source for pumping water and for grinding grain into flour
- Water
  - Energy source of waterwheels used for various purposes from agriculture to metallurgy

Fossil Fuels Vital to Human Progress

Fossil fuels that powered Industrial Revolution enabled

- transition from manual hard labor and horsepower to harnessing power of the atom
- feeding and sheltering of today's populace – inconceivable to likes of 18th century economist Thomas Malthus who believed population growth would outpace available food supply, leading to war, famine, and epidemic

Urbanization, industrialization, and energy consumption have contributed to an extension of life expectancy of **over 40 years…**


Life expectancy, 1800 to 2019
Our World in Data
World
70 years
60 years
50 years
40 years
30 years
1800
1850
1900
1950
2000
2019
Source: Riley (2005), Clio Infra (2015), and UN Population Division (2019)
OurWorldInData.org/life-expectancy • CC BY
Note: Shown is period life expectancy at birth, the average number of years a newborn would live if the pattern of mortality in the given year were to stay the same throughout its life.

ENVIRONMENTAL PROGRESS

Source: Nikos Alexandratos and Jelle Bruinsma, "World Agriculture Towards 2030/2050: The 2012 Revision," ESA Working Paper no. 12-03, Agricultural Develop- ment Economics Division, Food and Agriculture Organization of the United Nations, June 2012, http://www.fao.org/3/a-ap106e.pdf.

Why Retreat to Pre-Industrial Revolution Energy Resources?

Question: What is motivation for returning to pre-Industrial Revolution energy resources (i.e., 100% “renewables” economy that bans use of all fossil fuels)?

Answer: Allegedly, climate change (i.e., catastrophic anthropogenic global warming); conceals power play by globalists and tyrants to restrict human freedoms and take control of people’s lives

Retreat to Pre-Industrial Revolution Energy Resources (cont.)

Since very significant aspect of climate change hoax involves production of electricity needed for human prosperity, remainder of presentation focused on electricity-generating resources

Producing Electricity from Energy Resources

Important considerations in choosing energy resources for generating electricity

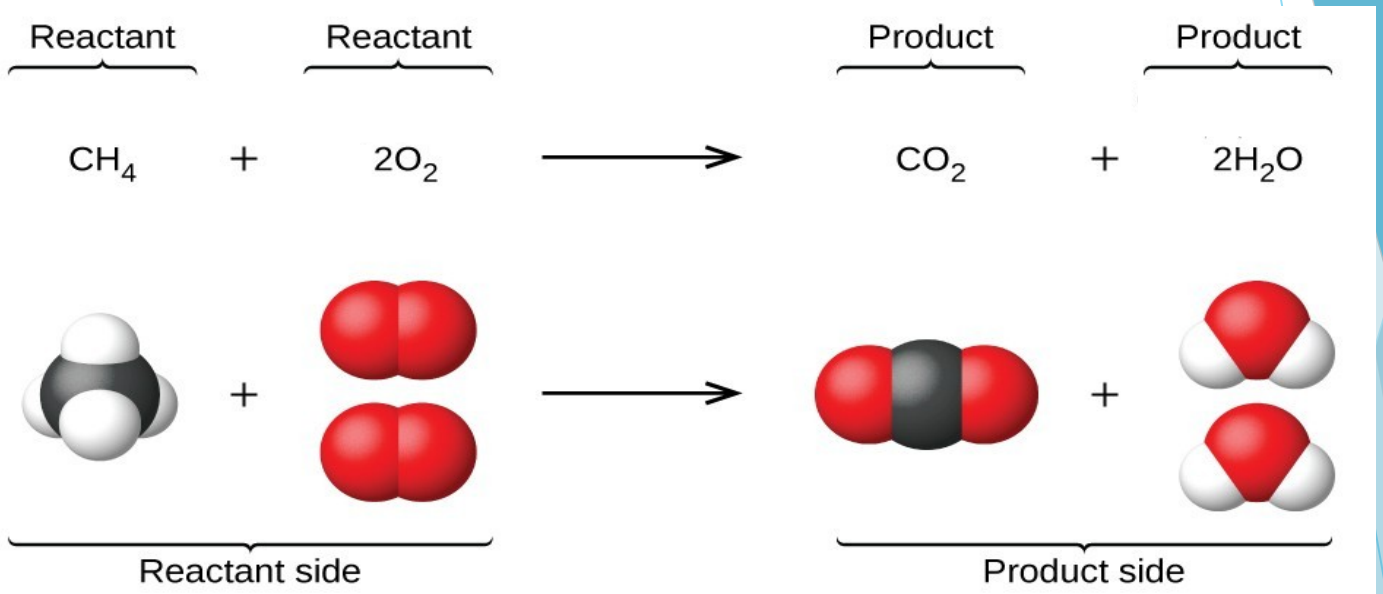
- **Resource energy density** – determines amount of energy resource that must be acquired to produce desired amount of electricity
- **Energy conversion efficiency** – how much of resource's energy content actually converted to electricity
- **Capacity factor** – percent of time electricity-generating system actually produces nameplate electricity

Fossil Fuels

- Fuels formed over millions of years by natural processes such as decomposition of buried dead organisms

- Type of energy – chemical
- Reaction of fossil fuels (hydrocarbons) with oxygen converts chemical energy to thermal energy
- Used as heat source in electricity-generating power plants

Chemical Reaction

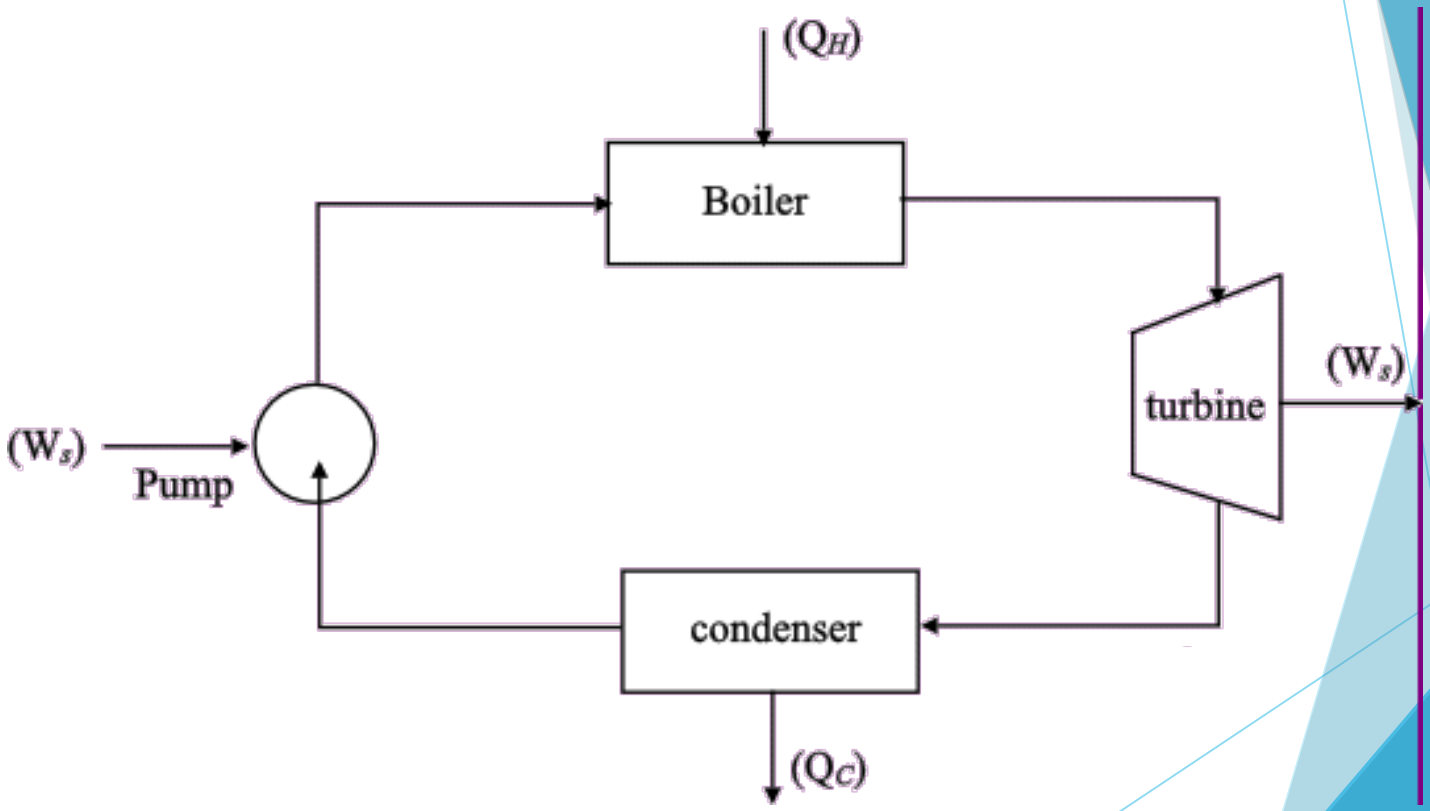


Burning (oxidation) of methane (CH_4) liberates about 50 MJ (14 kWh) of energy per kilogram of methane

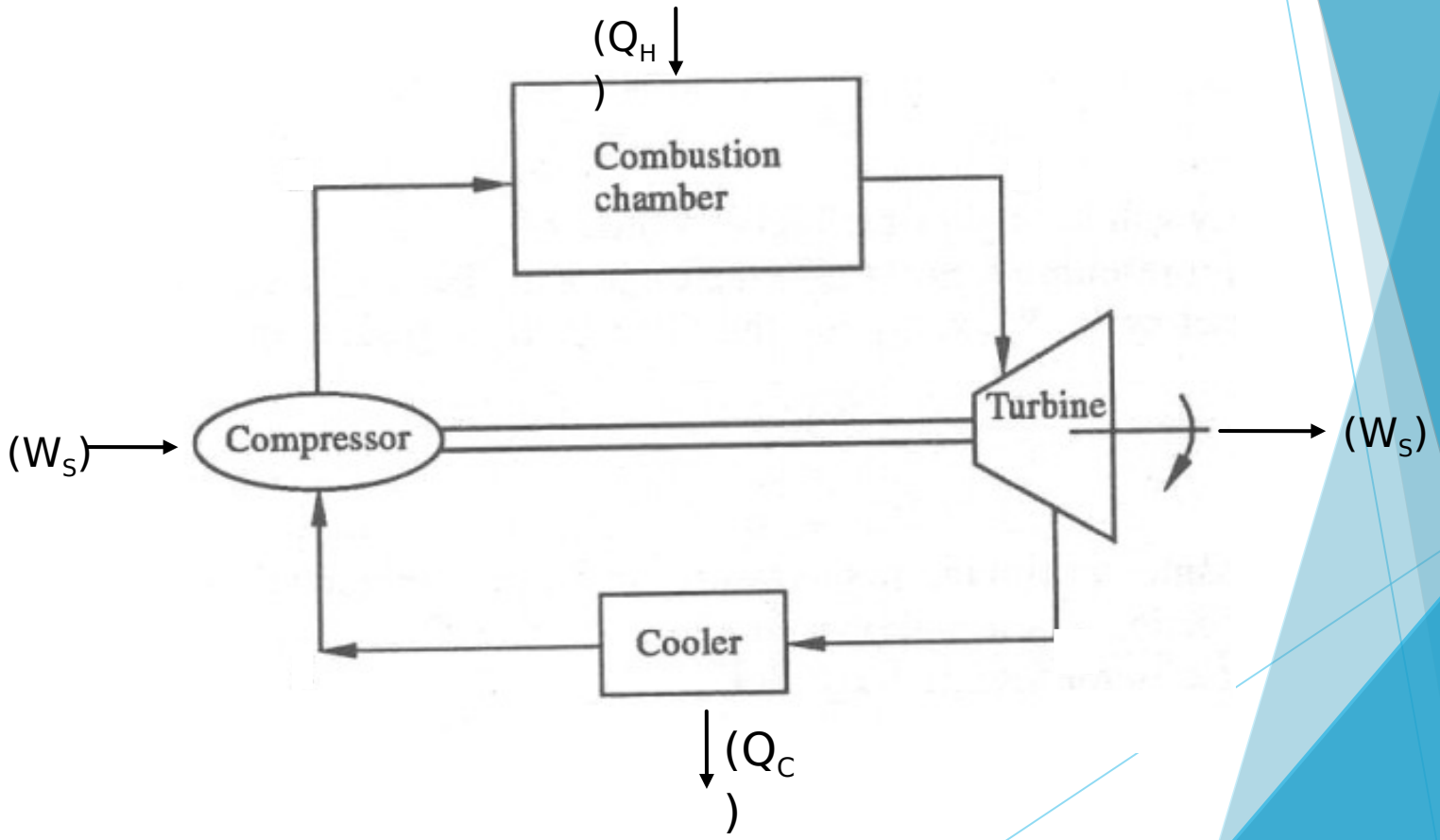
Conversion of Heat Energy to Electricity

- Primary processes for converting energy (heat) from combustion of fossil fuels to mechanical energy
  - Rankine cycle – steam cycle power plant
  - Brayton cycle – gas turbine power plant
- Mechanical energy of rotating turbine shaft drives electrical generator to produce electricity

Basic Steam Cycle Power Plant (Rankine Cycle)



Basic Gas Turbine Power Plant (Brayton Cycle)

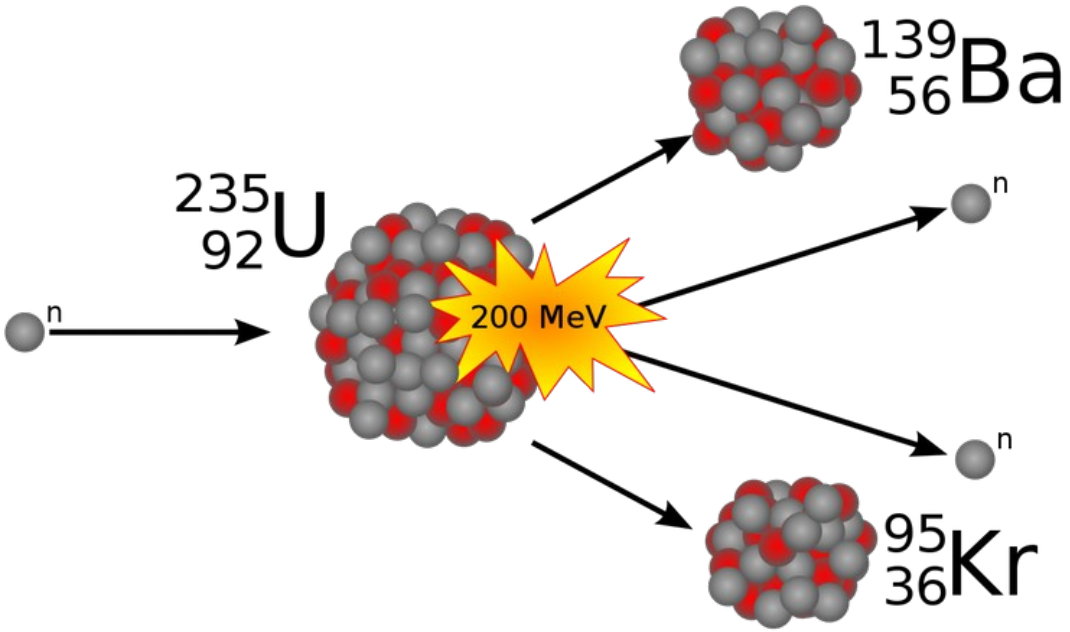


Nuclear Energy

- Energy contained in nucleus of heavy atoms like uranium
- Type of energy – nuclear (originating in nucleus of ato

- Uranium fission converts nuclear energy to thermal energy in nuclear reactor fuel elements
- Generally used as heat source in steam cycle power plant to produce electricity

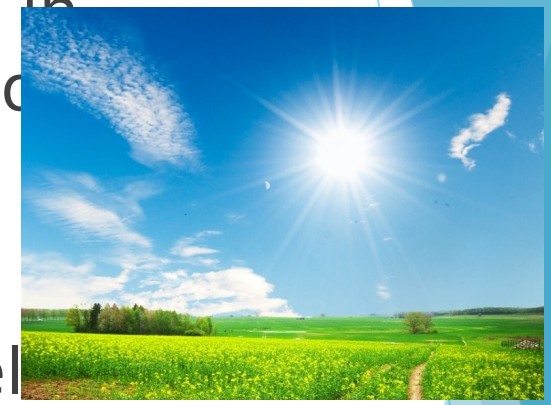
Fission of U-235 Nucleus



Splitting of the U-235 nucleus liberates about 200 MeV of energy
(about 80 million MJ, or 22 million kWh, per kilogram of U-235)

Solar Energy

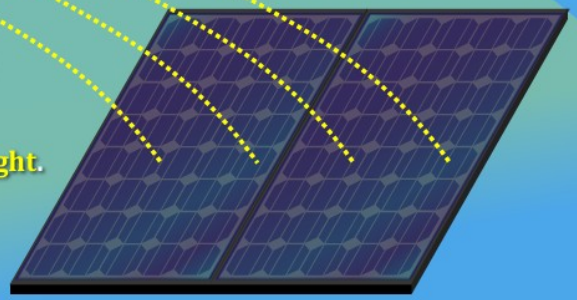
- Transmitted to earth from sun in packets of energy called photo
- Type of energy – radiant
- Radiant energy (photons) incident on photovoltaic panel converted directly to electricity or to thermal energy (waste heat) depending on photon energy

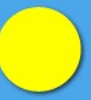


How solar energy is converted to electricity

Photons of light strike the surface of a solar panel, but only some are strong enough to produce an electrical current.

pho·to·vol·ta·ic
/fōdō,vōl'tāik/
adjective
Electrified by **light**.





Photons with the right amount of energy excite electrons that flow through wires to power your home.

Photons that are too strong also excite electrons, but their extra energy causes the cell to heat up

Photons that are too weak can't excite electrons, and also add heat to the solar cell.

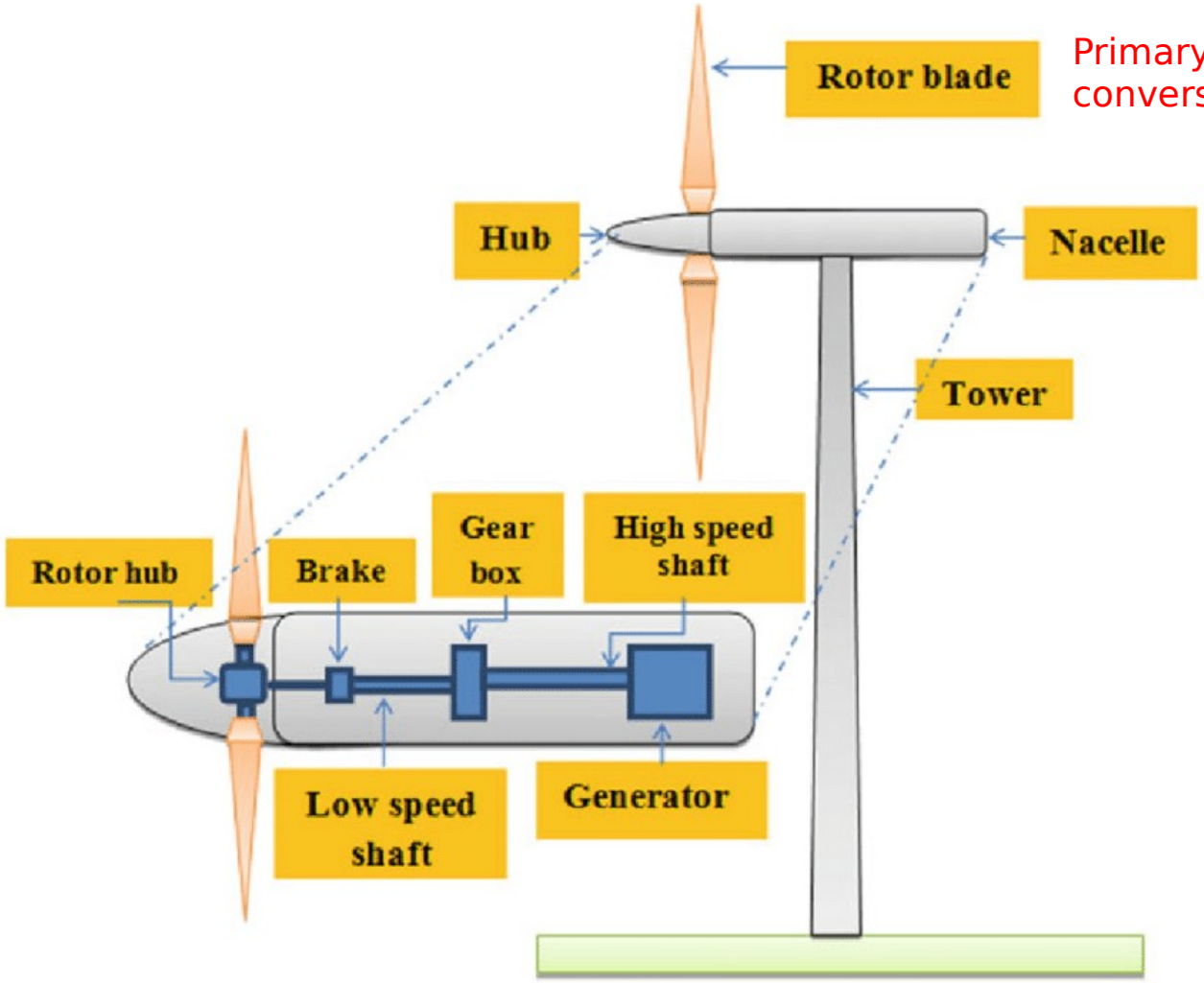
Solar Power Rocks

Wind Energy

- Energy in air mass movements created by sun's heating of Earth's atmosphere, Earth's rotation, and Earth's surface irregularities

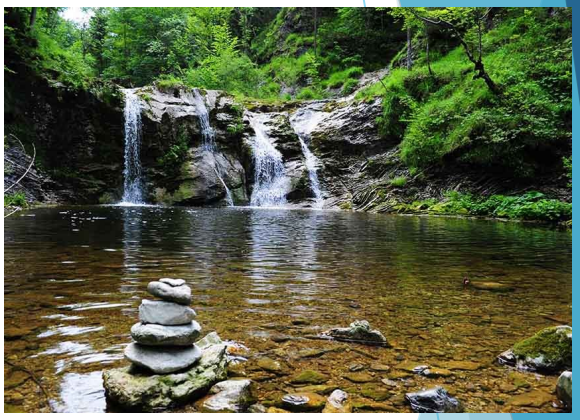
- Type of energy – kinetic (air mas in motion)
- Wind turbine converts wind (kinetic) energy to mechanical energy in rotating shaft, which drives gearbox and electrical generator to produce electricity

Wind Energy Conversion

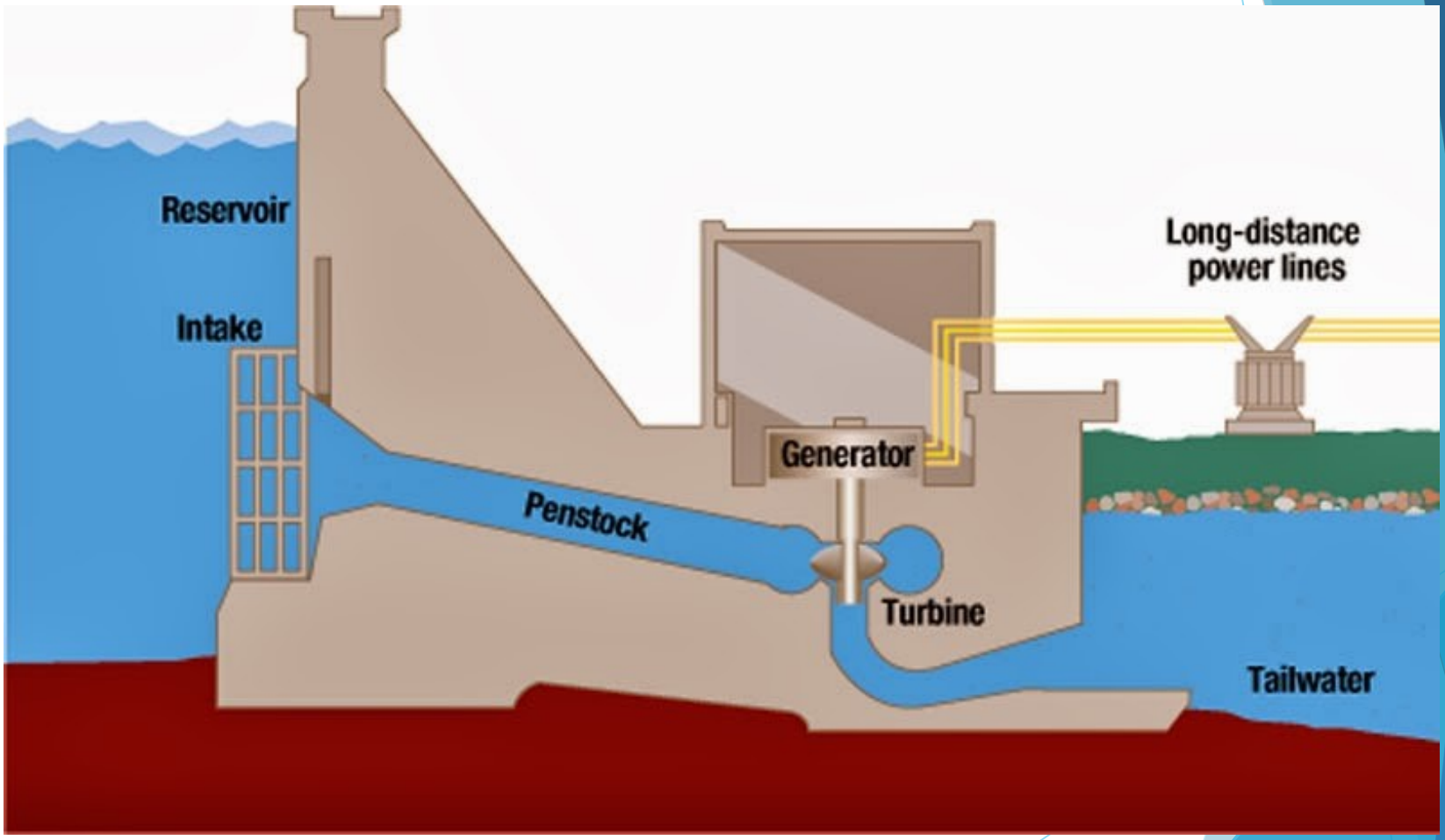


Water Energy

- Water accumulated behind a dam has potential (gravitational) energy
- Type of energy – kinetic (water mass in motion)
- Water turbine converts kinetic energy of water into mechanical energy in rotating shaft, which drives an electrical generator to produce electricity



Flowing Water Energy Conversion



No “Clean” Energy

- Both positive and negative aspects to obtaining useful work from all energy resources
- No energy resource is “free” or “clean”
  - Both direct and indirect costs associated with acquiring resources, manufacturing equipment, and facilities to produce useful energy we consume daily
  - Entire **life-cycle** associated with using any energy resource to obtain useful energy results in byproducts and waste that can adversely affect environment
  - American public generally hears only about how “clean” operating solar and wind energy facilities are; seldom, if ever, hear about wastes generated and environmental damage incurred from mining and manufacturing materials necessary to construct and operate solar and wind electricity-generating facilities

Energy Resource Life-cycle

Raw Material Extraction/Refining

- Raw materials must be mined and processed to obtain useful building and manufacturing materials
- Processed material resources are required for the construction and operation of facilities that
  - refine raw materials
  - manufacture the machines, devices, and equipment for energy conversion and electricity transmission
  - convert energy resources to electricity

Manufacturing/Production

- The structural materials for constructing facilities to refine raw materials, manufacture energy conversion devices/equipment, and convert energy resources to electricity must be produced.
- The machines, devices, and equipment for operating these facilities must be produced.

Transportation

Transportation resources are required to get

- raw materials to refining facilities
- processed materials to manufacturing facilities
- construction materials and equipment to facility construction sites
- machines, devices and equipment to energy resource conversion locations

Waste Disposal/Recycling

Wastes produced in each phase of the life-cycle, as well as equipment and structures that are no longer usable, require appropriate dispositioning.

Electricity-Generating System Performance

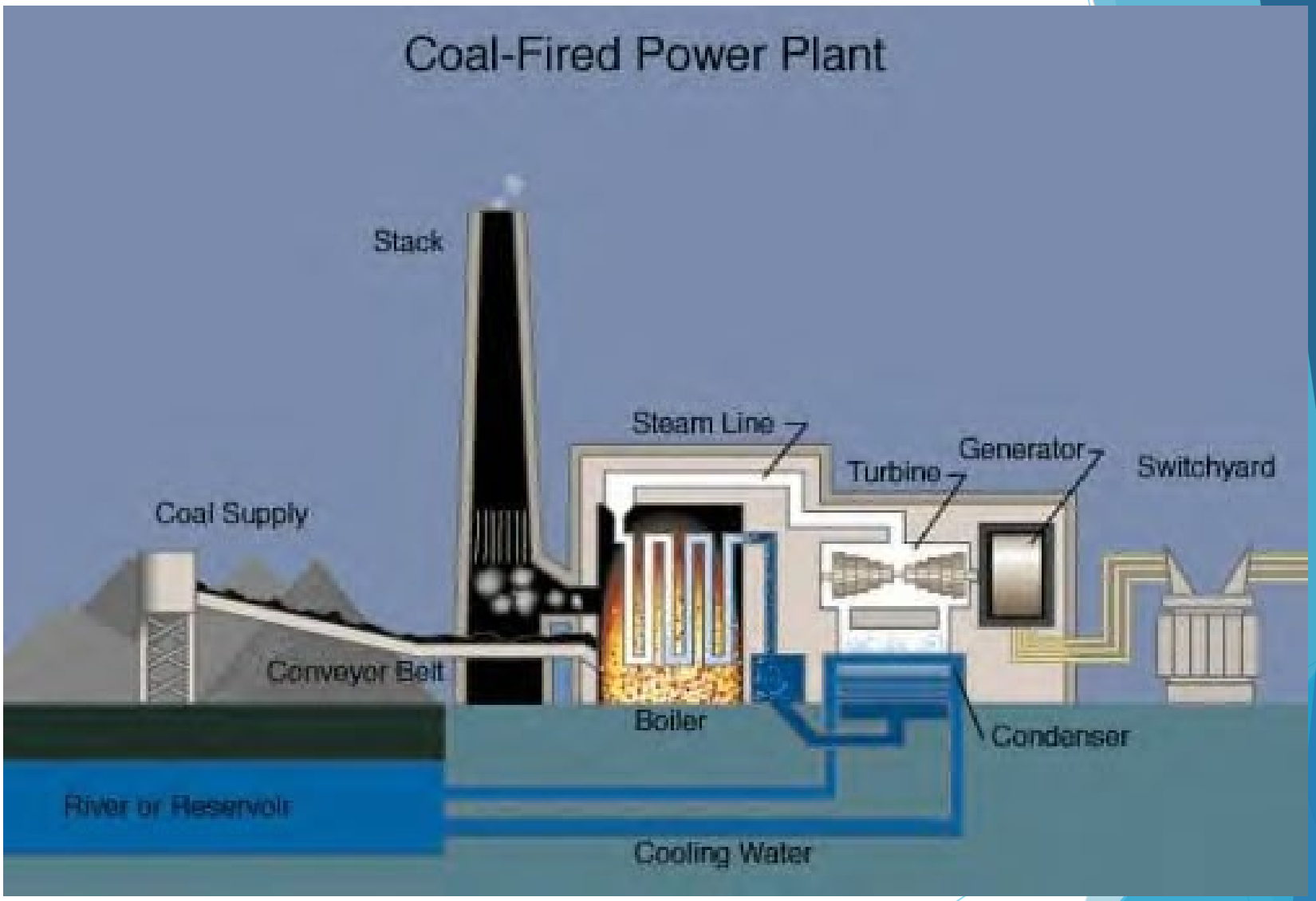
Important performance measures to consider when deciding among available electricity-generating technologies

- Energy conversion efficiency
  - Ratio of useful energy to available energy
- Electricity-generating system capacity factor
  - Ratio of actual electrical energy output over given period of time to maximum possible electrical energy output over that time period

Assessing Energy Conversion System Efficiencies

Energy Conversion Efficiencies

Initial energy form	Converted energy form: Mechanical	Electric	Radiant	Chemical	Thermal
Mechanical		Generator 95-99%			Brake drum 100%
Kinetic	Water turbine 86%				
Electric	Electric motor 65-93%		Lamp incandescant 5-8% flourescent 25-30%	Storage battery 72%	Heating coil 100%
Radiant		Solar cell 15-27%		Photosynthesis 0.6%	Solar furnace 100%
Chemical	Muscle 45%	Dry cell battery 91%			Furnace of steam boiler 85-88%
Thermal	Steam turbine 40-47%				


Coal-Fired Power Plant
Stack
Steam Line
Generator
Turbine
Switchyard
Coal Supply
Conveyor Belt
Boiler
Condenser
River or Reservoir
Cooling Water

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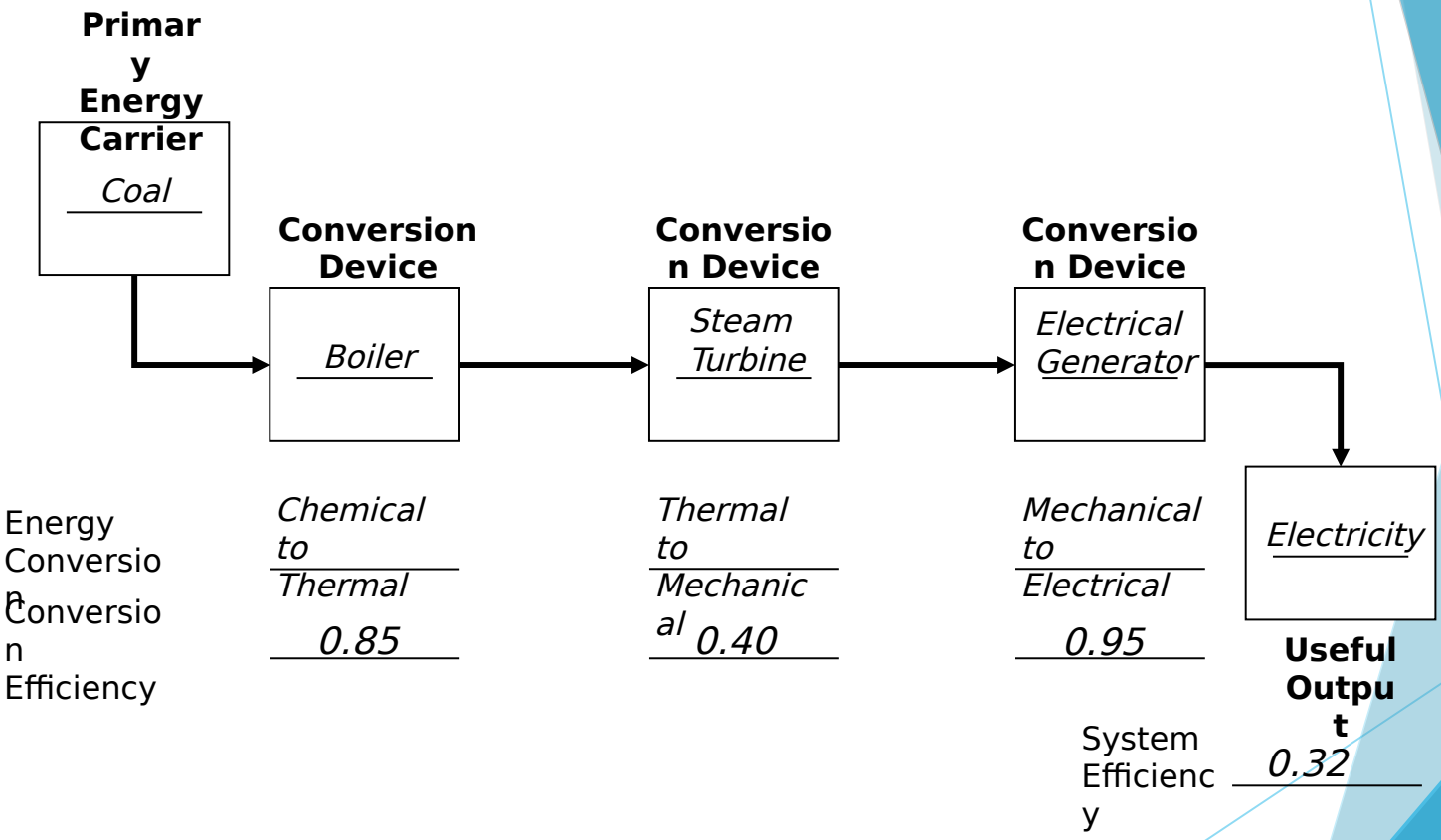
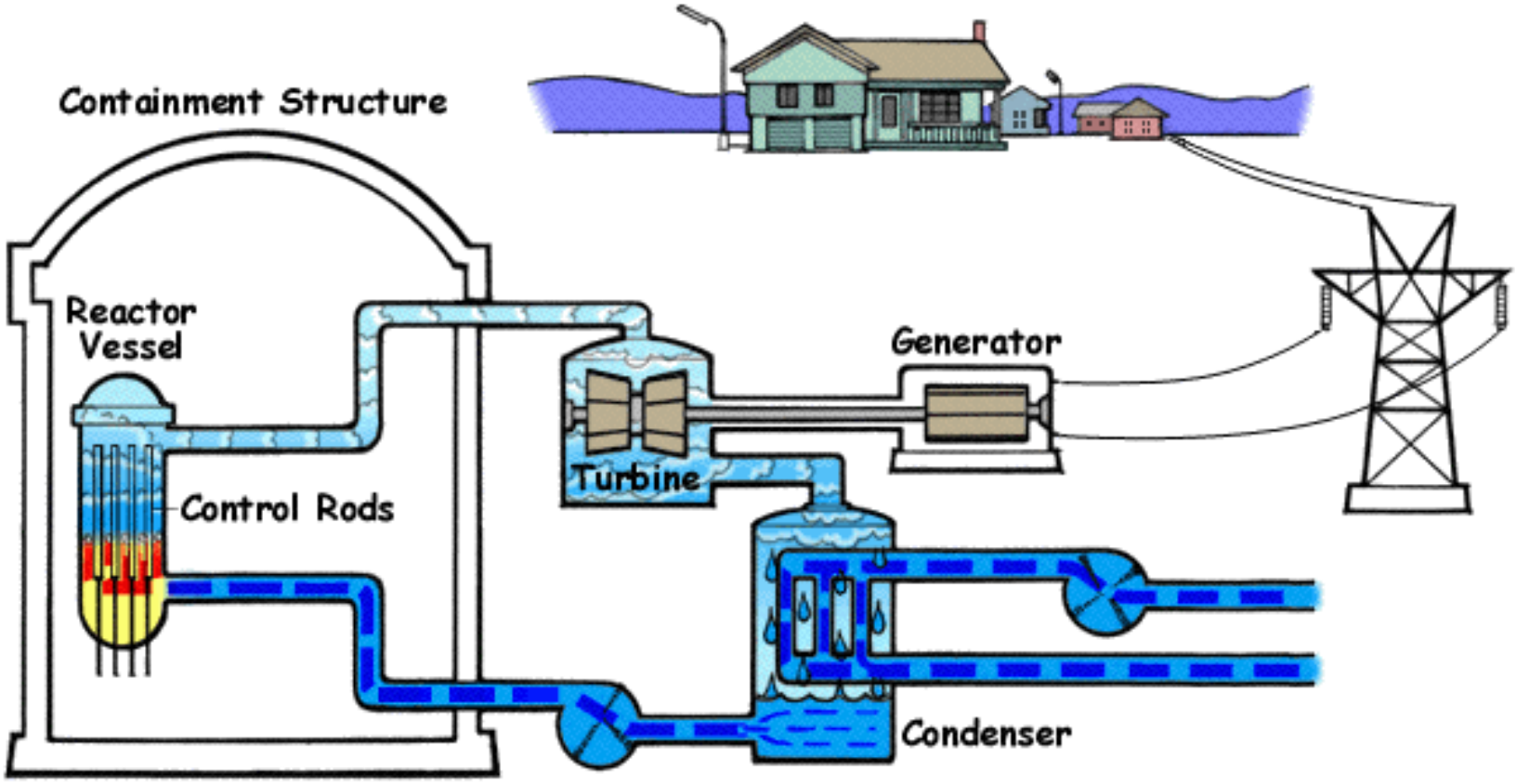
Coal-fired Power Plant Efficiency



Boiling Water Reactor Plant



Nuclear Fission Energy Disposition

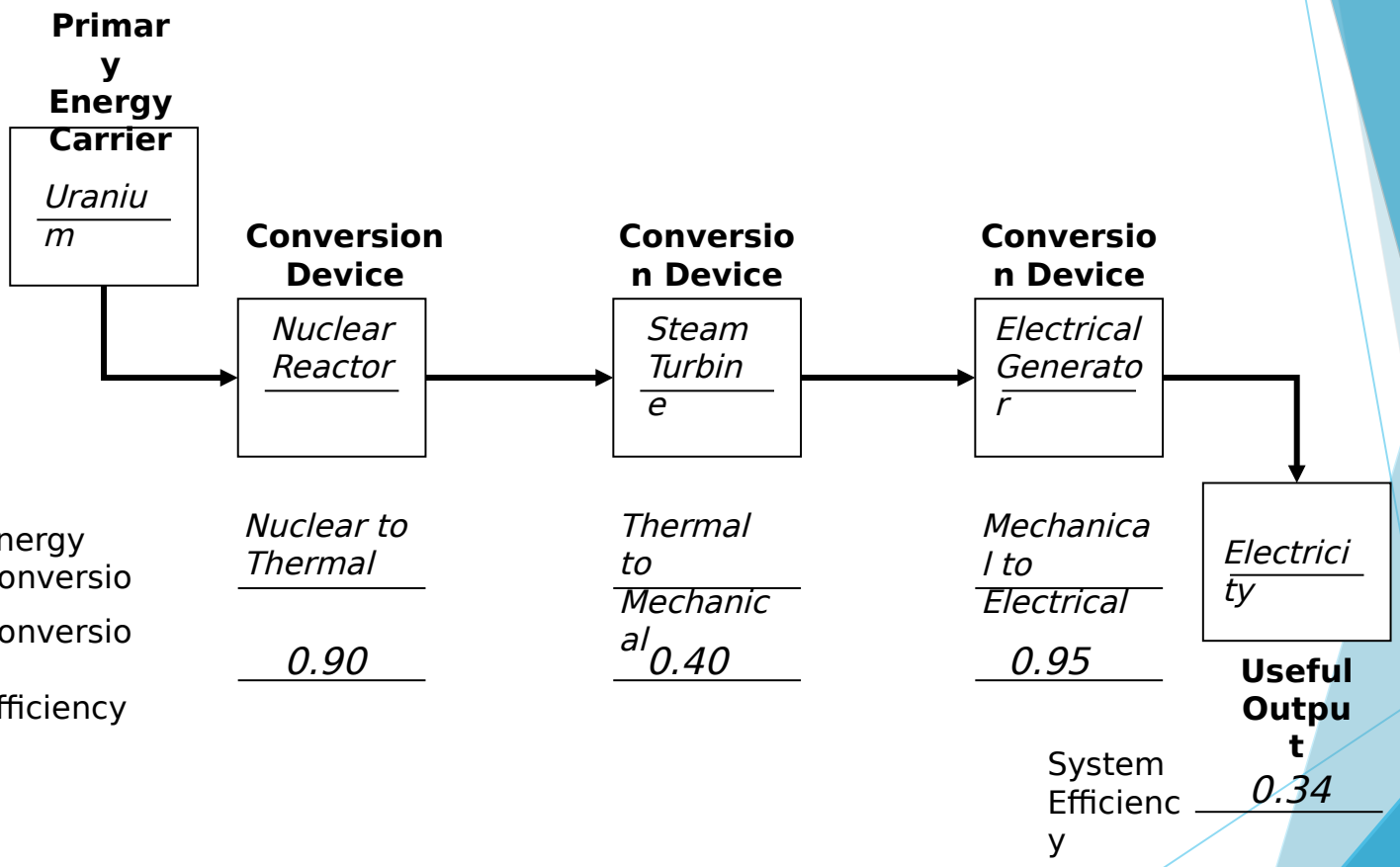
	Mev	%
Fission Fragment Kinetic Energy	168	84
Fission Neutron Kinetic Energy	5	2.5
Prompt Gamma Ray Energy	7	3.5
Fission Fragment Delayed Radiation		
Beta Particles	8	4
Gamma Rays	7	3.5
Radiative Capture Gamma Rays*	5	2.5
Total	200	100

* Non-fission capture reactions contribute thermal energy to system

Kinetic energy of fission fragments and delayed beta radiation energy deposited within the nuclear fuel material as thermal energy

Most of fission neutron kinetic energy deposited within reactor cooling water (neutron moderator) as thermal energy

Nuclear Power Plant Efficiency



Hydroelectric Power Plant

Energy Conversion Efficiencies

Initial energy form	Converted energy form: Mechanical	Electric	Radiant	Chemical	Thermal
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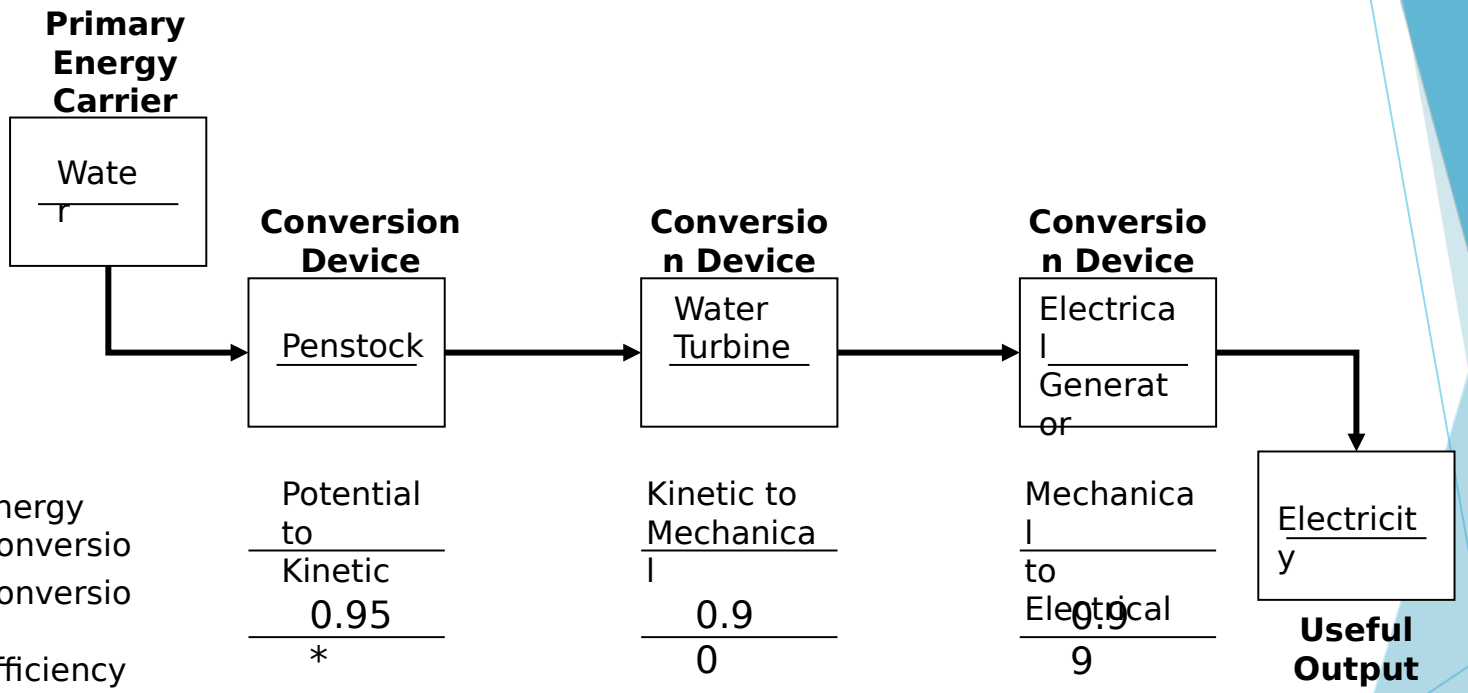
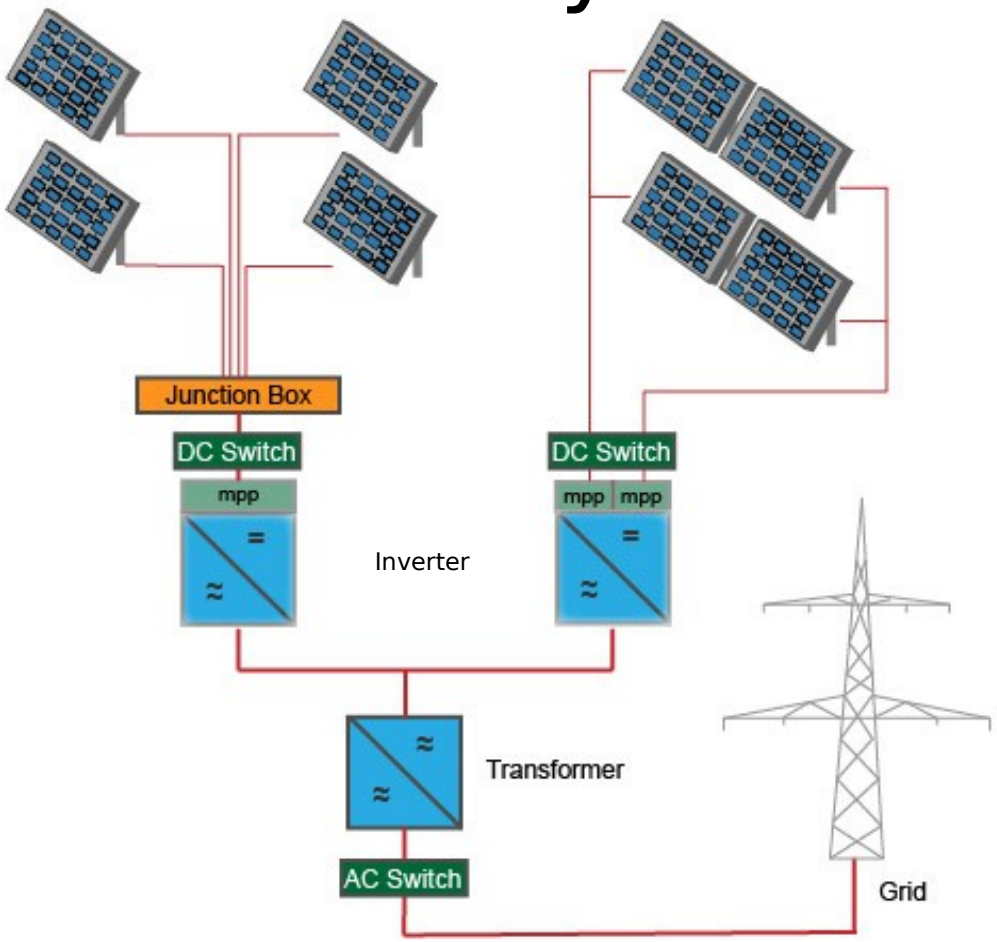
Hydroelectric Power Plant Efficiency

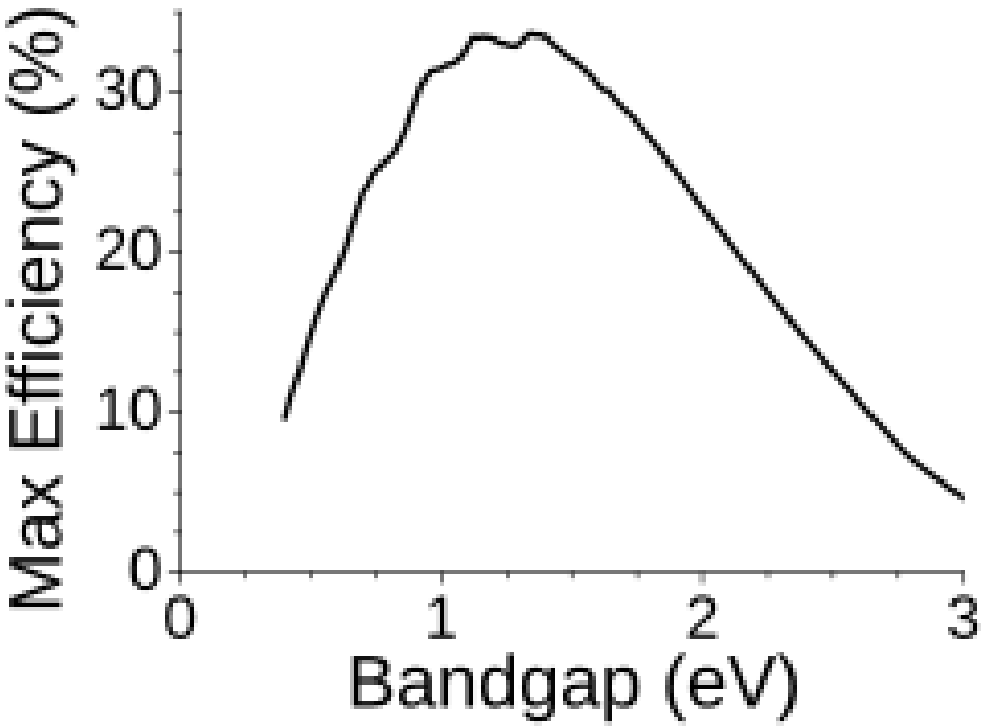


* While there is minimal energy loss in a hydroelectric facility penstock, a maximum efficiency of 95% is used.

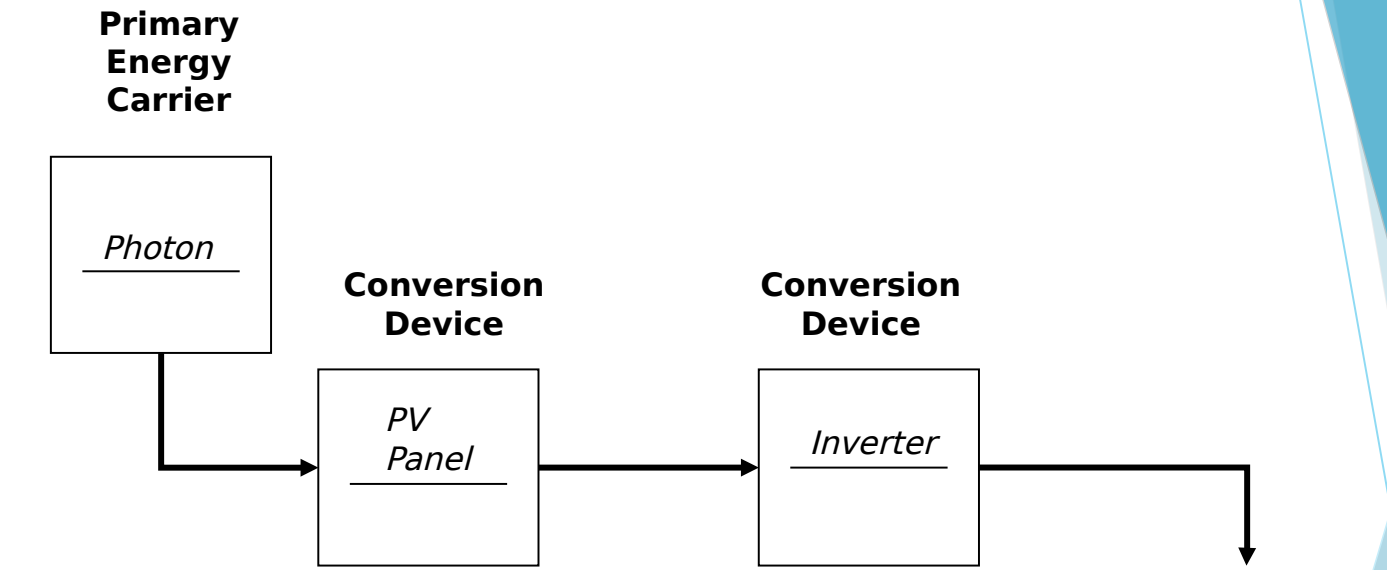
Photovoltaic Facility



Shockley-Queisser Limit for Silicon PV Cell Efficiency



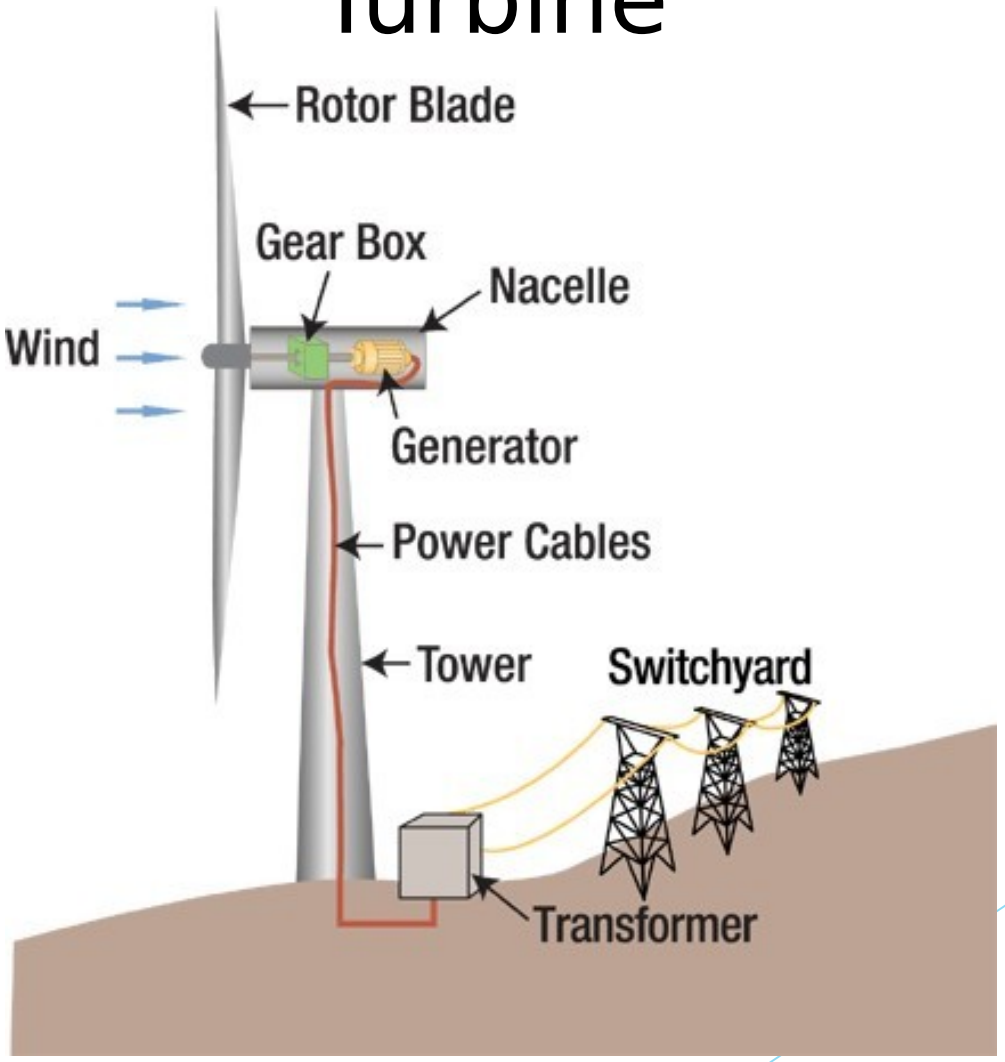
Solar (Photovoltaic) Power Facility Efficiency



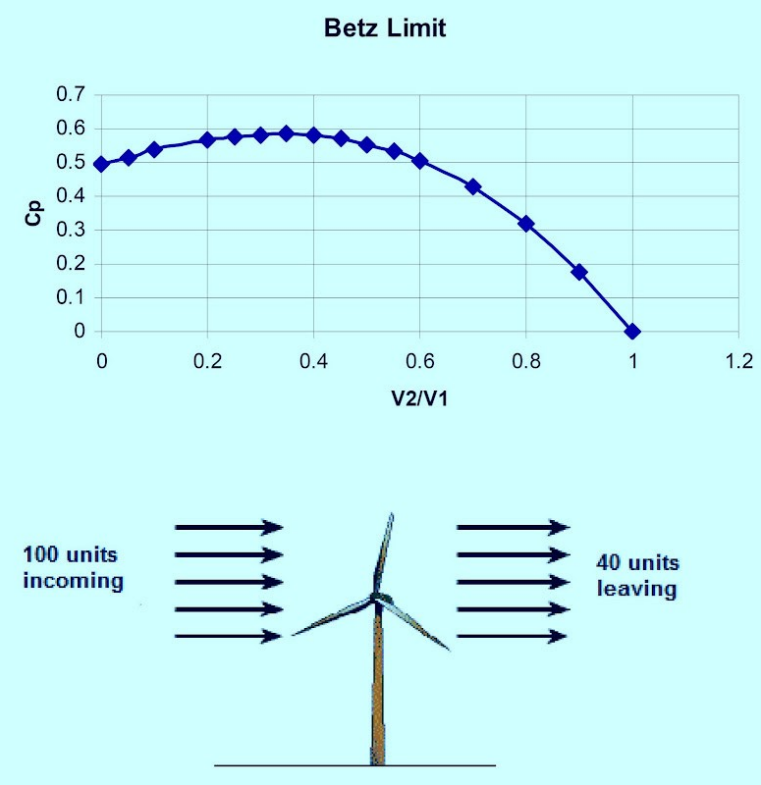
* See notes

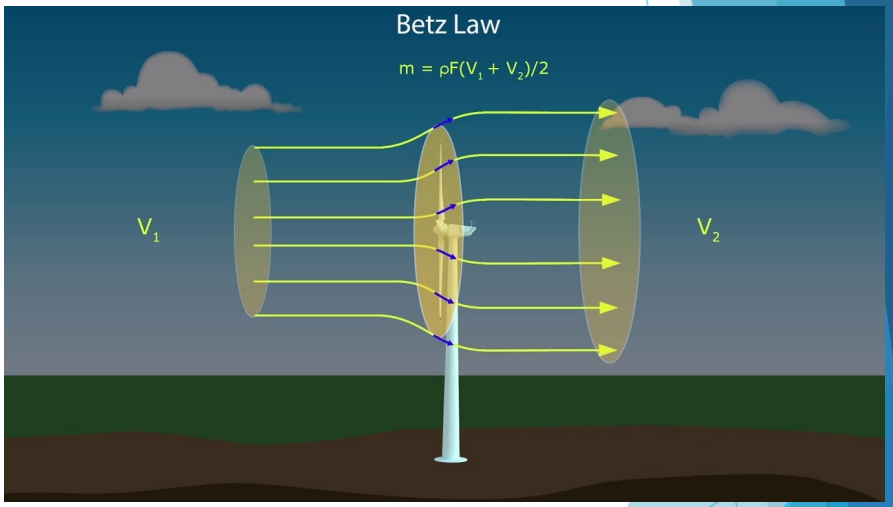
System Efficiency 0.19

Wind Turbine

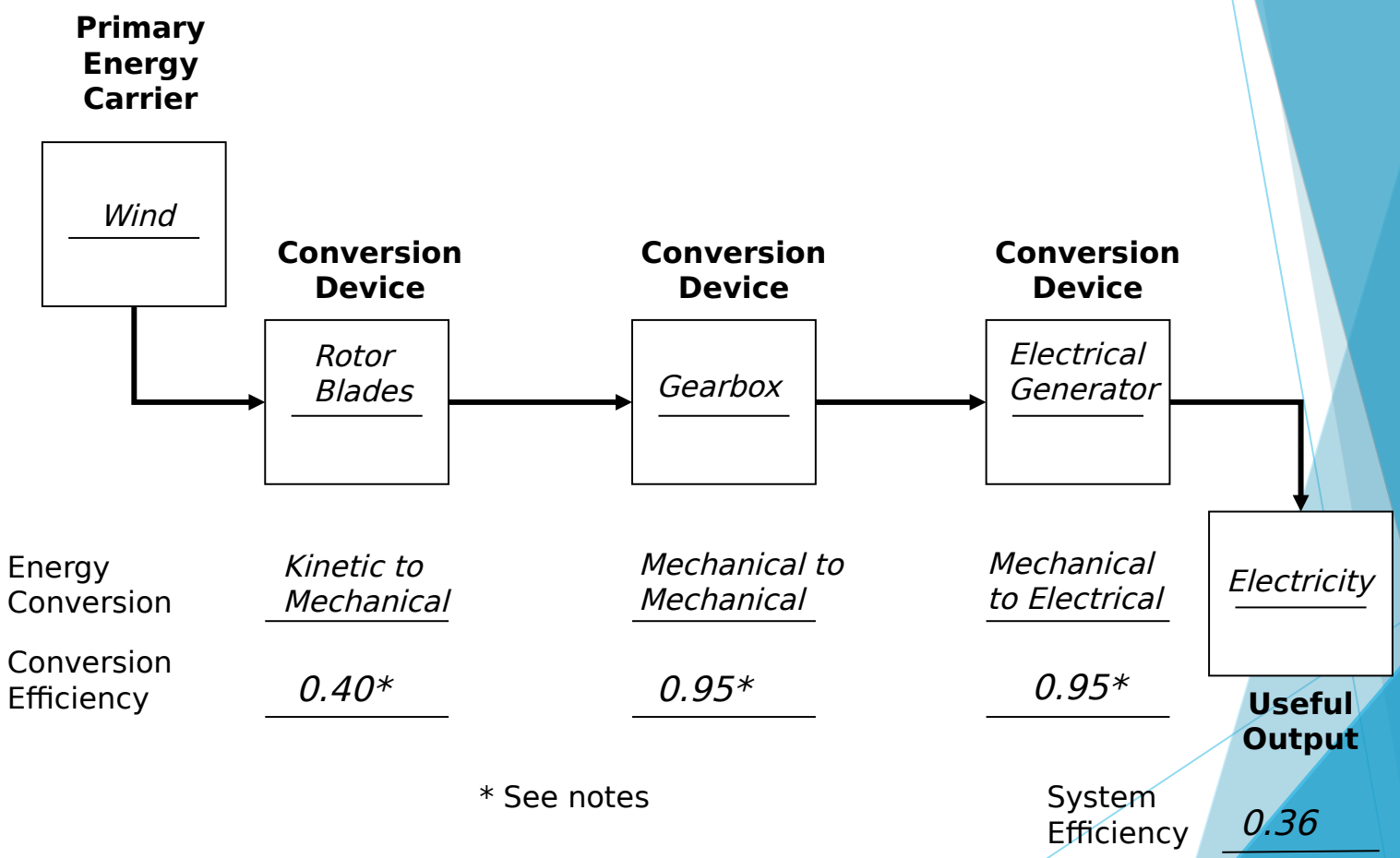


Betz Limit for Extracting Wind Power





Wind Turbine Power Facility Efficiency



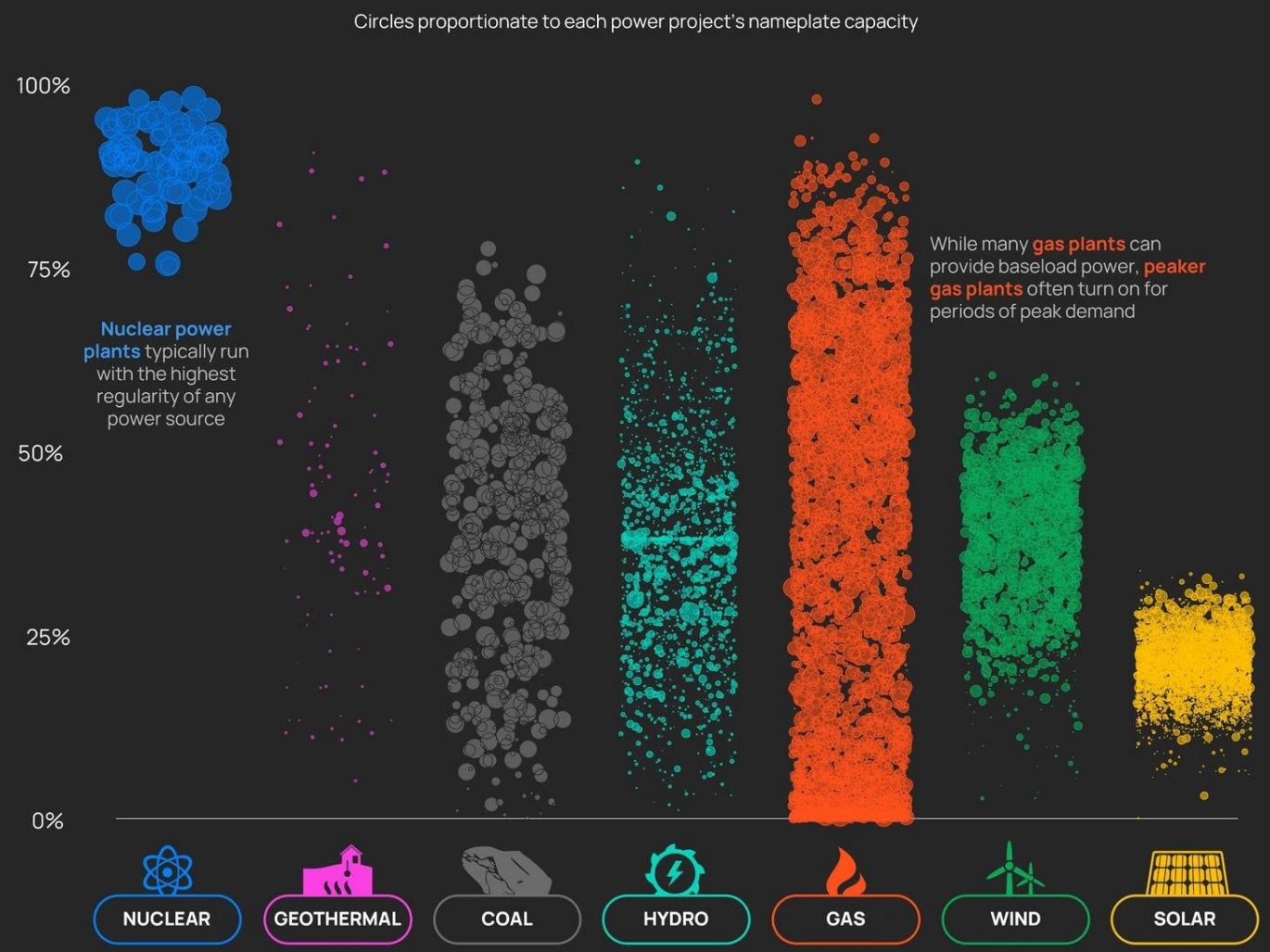
Electricity-generating System Efficiencies

Summary of calculated electricity-generating system efficiencies:

- Coal-fired power plant – 32%
- Nuclear power plant – 34%
- Hydroelectric plant – 84%
- Photovoltaic facility – 19%
- Wind turbine facility – 36%

CAPACITY FACTORS

Power plants rarely run at their full capacity around the clock. Instead, markets, the environment or economics influence how regularly a plant produces power.



Capacity factor: A percentage that measures how often a power plant operates at its maximum power output

Data source: US Energy Information Administration

ORENNIA

Electricity-generating System Average Capacity Factors

Energy System	Average Capacity Factor	Equivalent Full Power Days Per Year
Nuclear	92%	336
Geothermal	74%	270
Natural Gas	56%	204
Hydroelectric	41%	150
Coal	40%	146
Wind Turbine	35%	128
Photovoltaic	25%	91

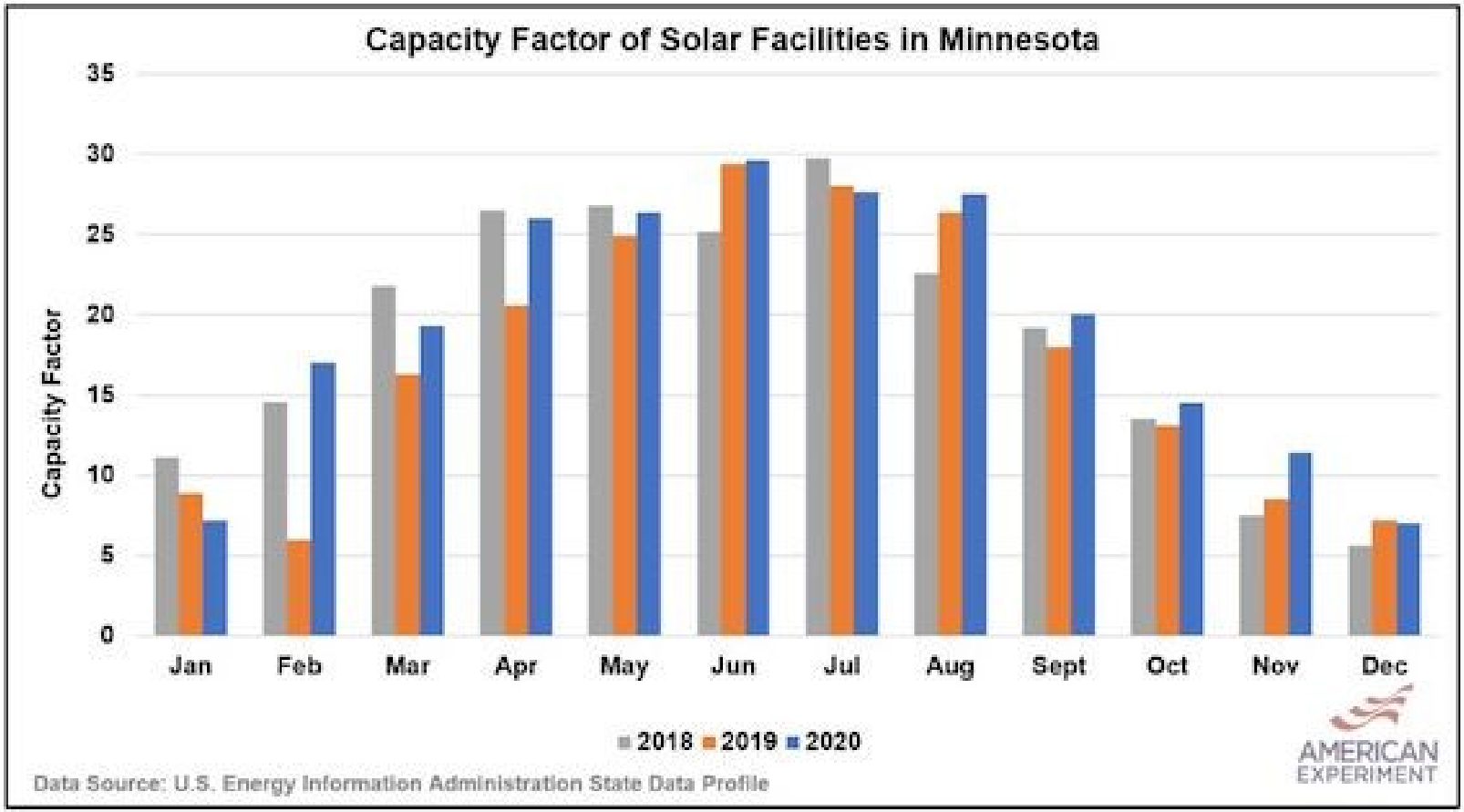
Source: Energy Information Administration, 2020

Conditions Influencing Electricity-generating System Capacity Factor

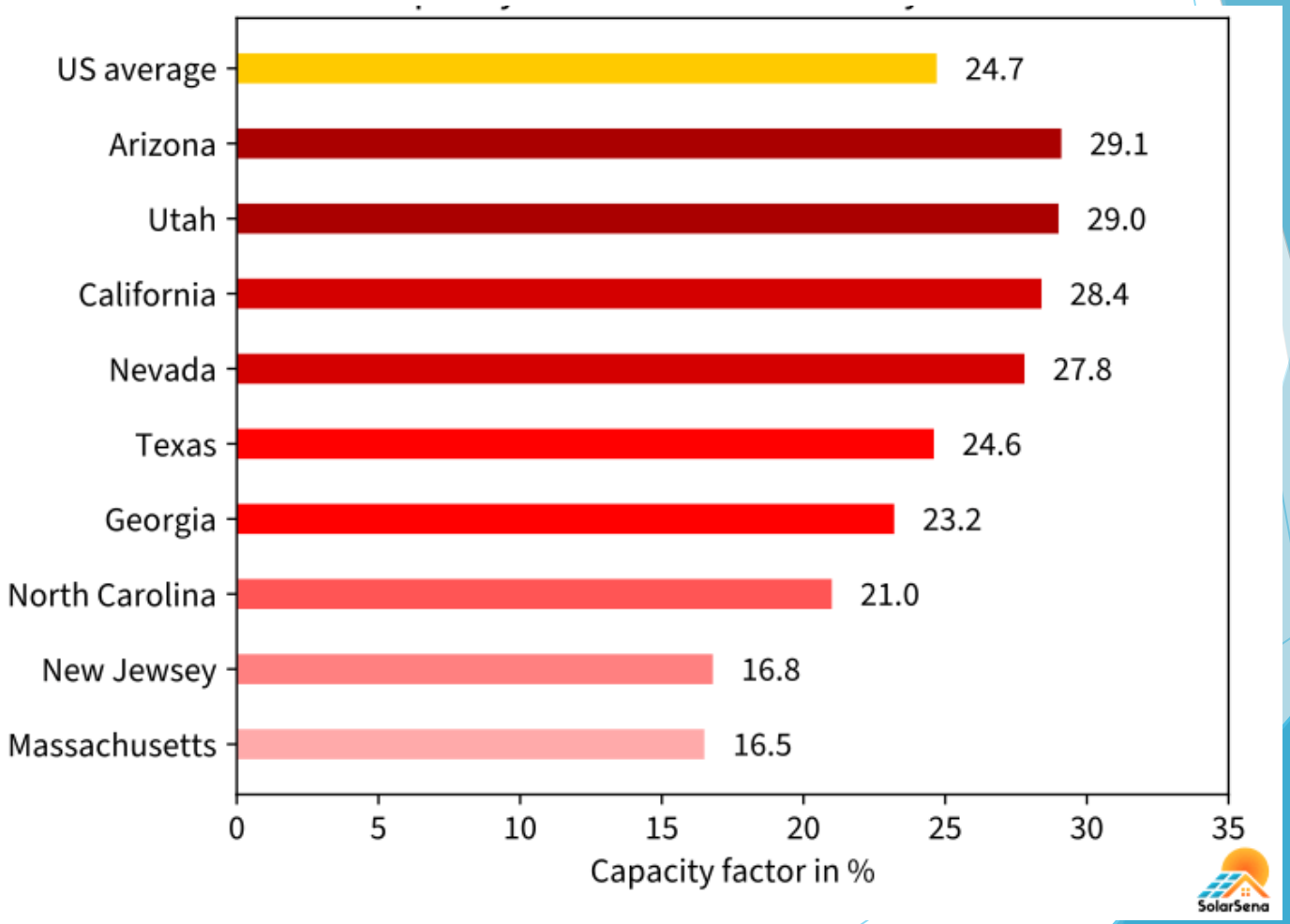
Conditions affecting system's actual electrical energy output include:

- Equipment failures
- Routine maintenance
- Electricity demand (esp. load-following units)
- Fuel availability (sun and wind)
- Environmental regulations (e.g., coal-fired units)

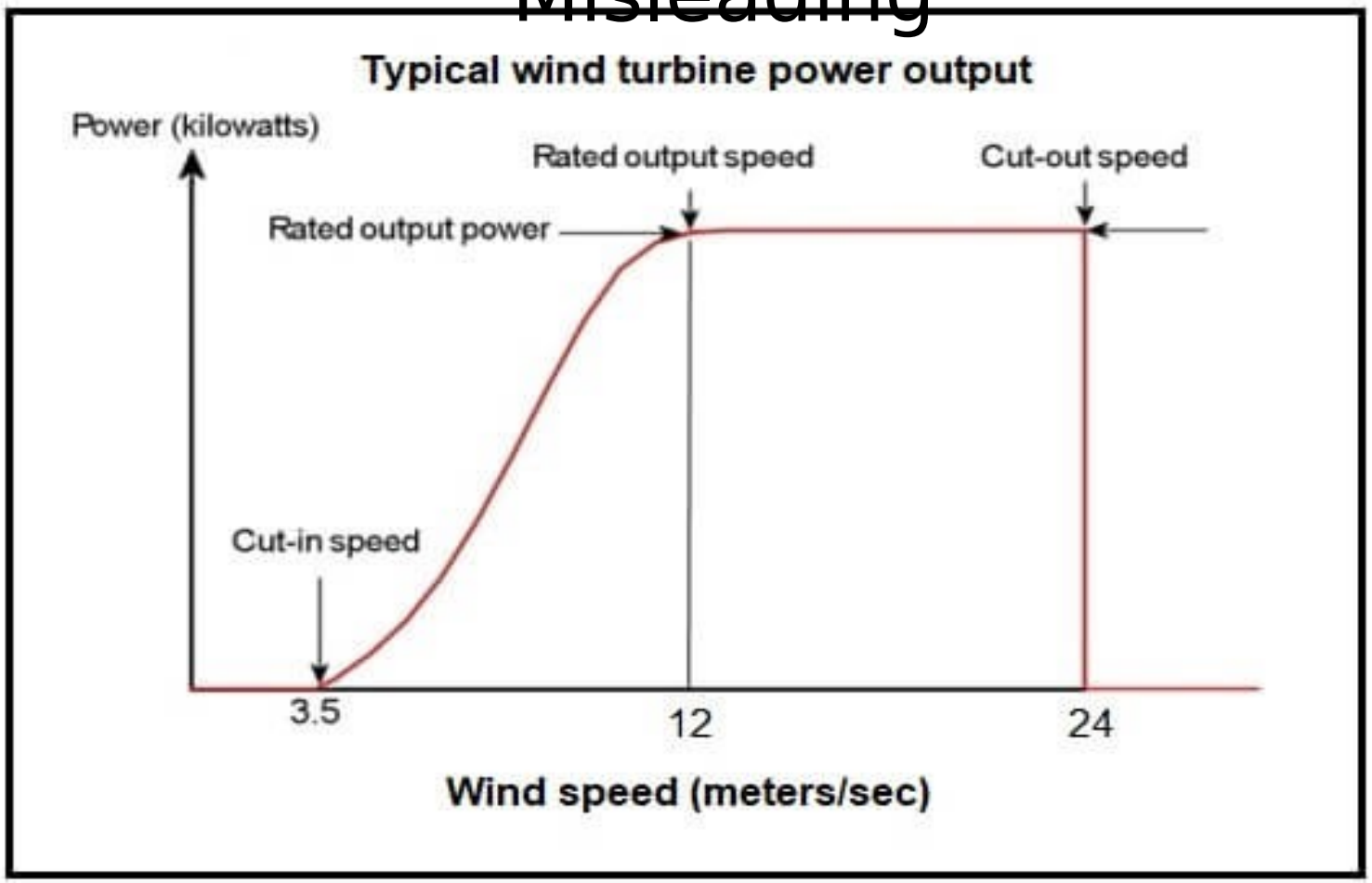
PV Average Capacity Factor Can be Very Misleading

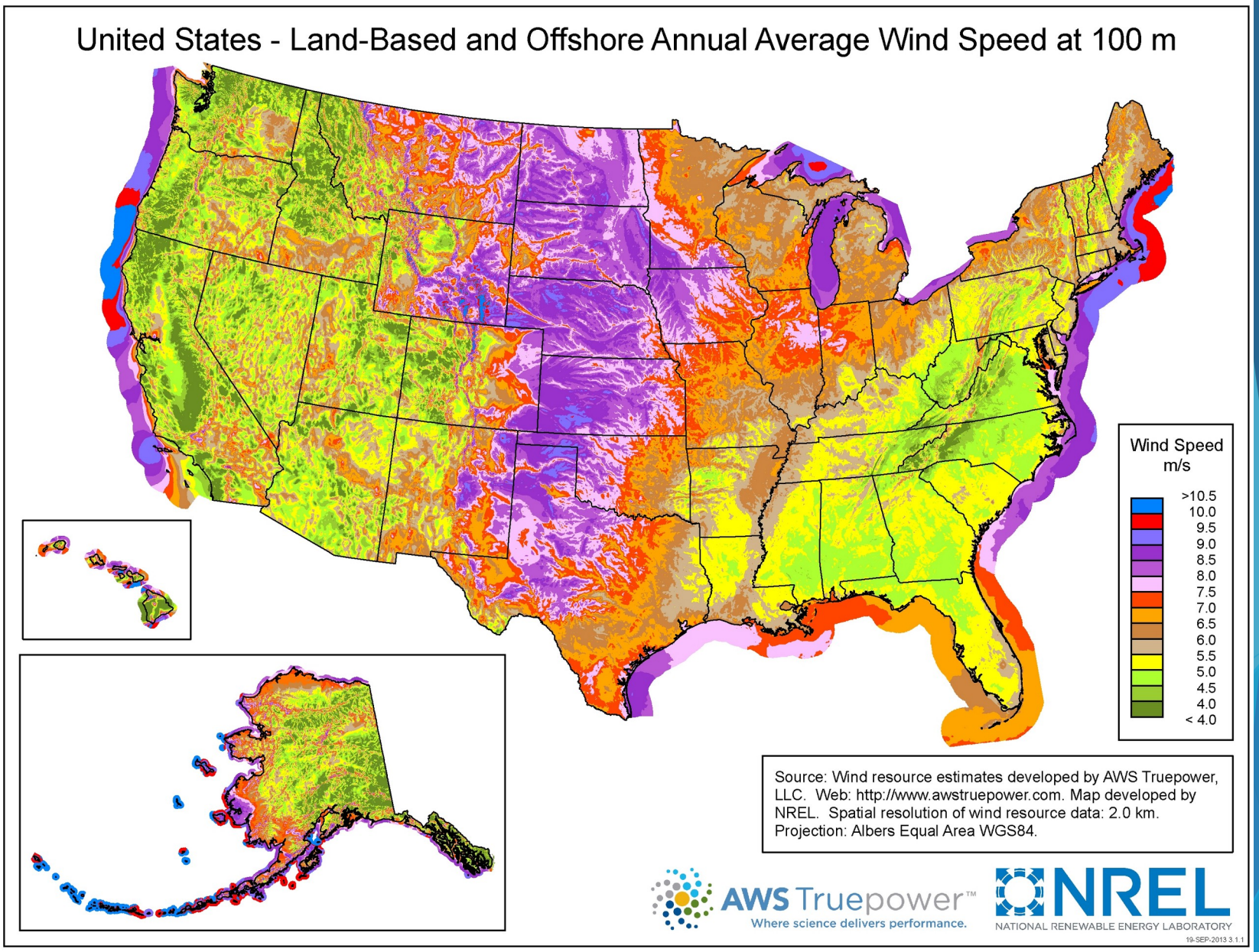


Capacity Factor of PV Systems in Some States



Wind Turbine System Average Capacity Factor Can be Very Misleading

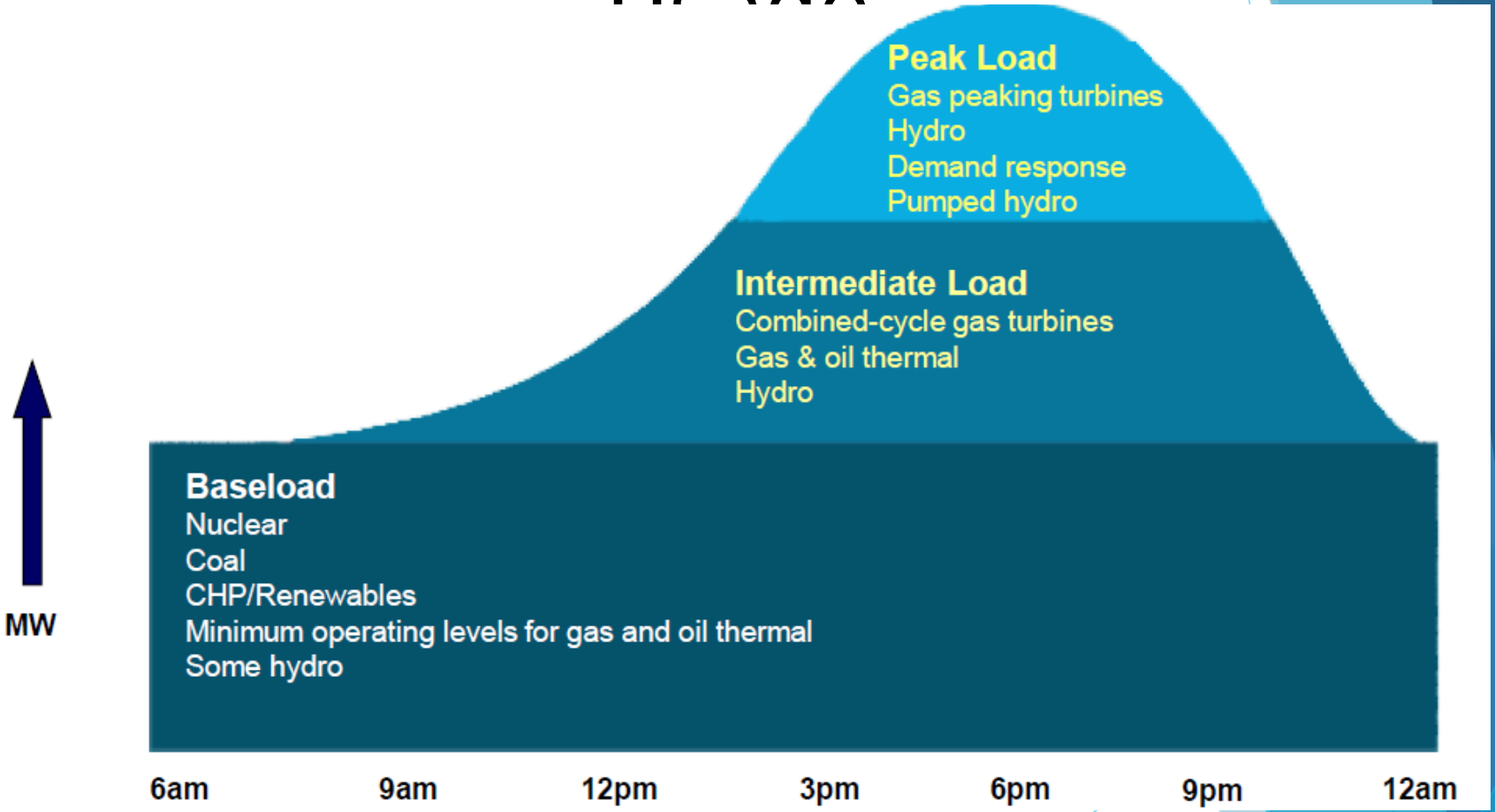



United States - Land-Based and Offshore Annual Average Wind Speed at 100 m
Wind Speed
m/s
>10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
Source: Wind resource estimates developed by AWS Truepower, LLC. Web: http://www.awstruepower.com. Map developed by NREL. Spatial resolution of wind resource data: 2.0 km. Projection: Albers Equal Area WGS84.
AWS Truepower™
Where science delivers performance.
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
19-SEP-2013 3.1.1

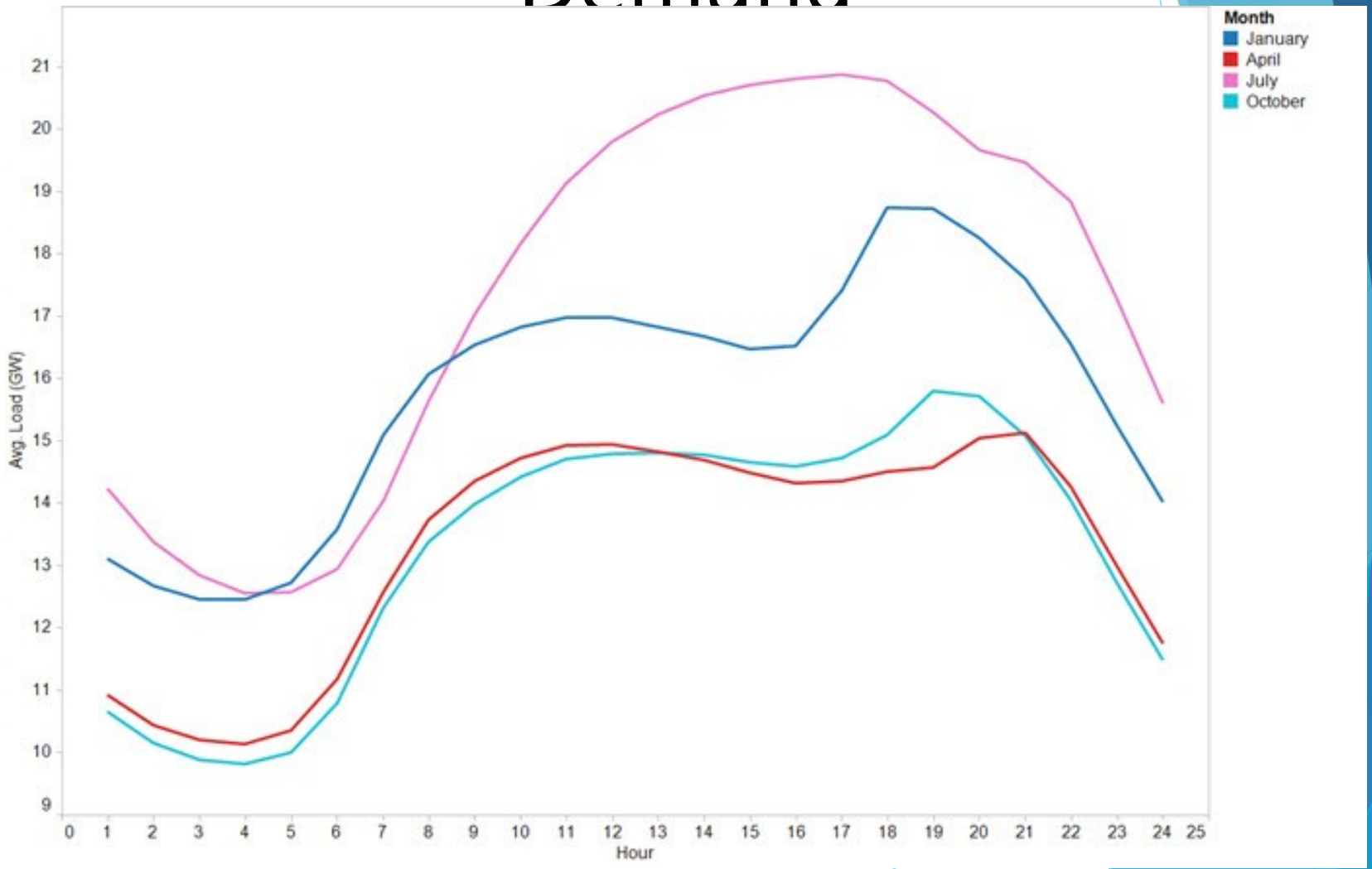
Not All Energy Resources are Equal

- Need to consider implications arising from 100% renewables grid
- Two types of demand, or loads, on electrical grid must be accommodated to meet residential and commercial needs
  - **Base load electricity** – minimum level of electricity demand required over period of 24 hours
  - **Peak load electricity** – maximum level of electricity demand exceeding base load level required over sustained period of time
- Solar and wind energy not suitable for generating base load electricity

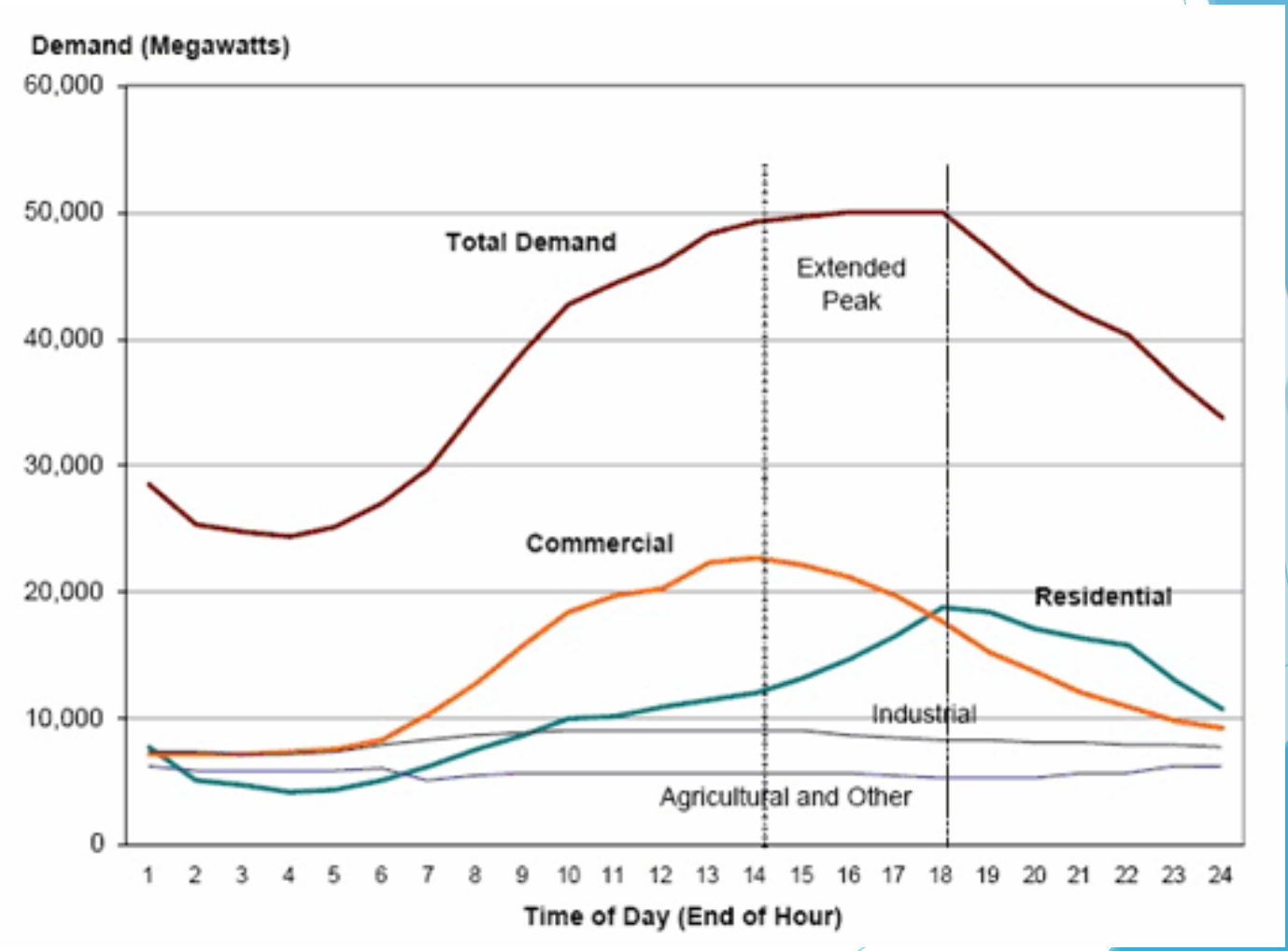
Typical Electricity Generation Usage



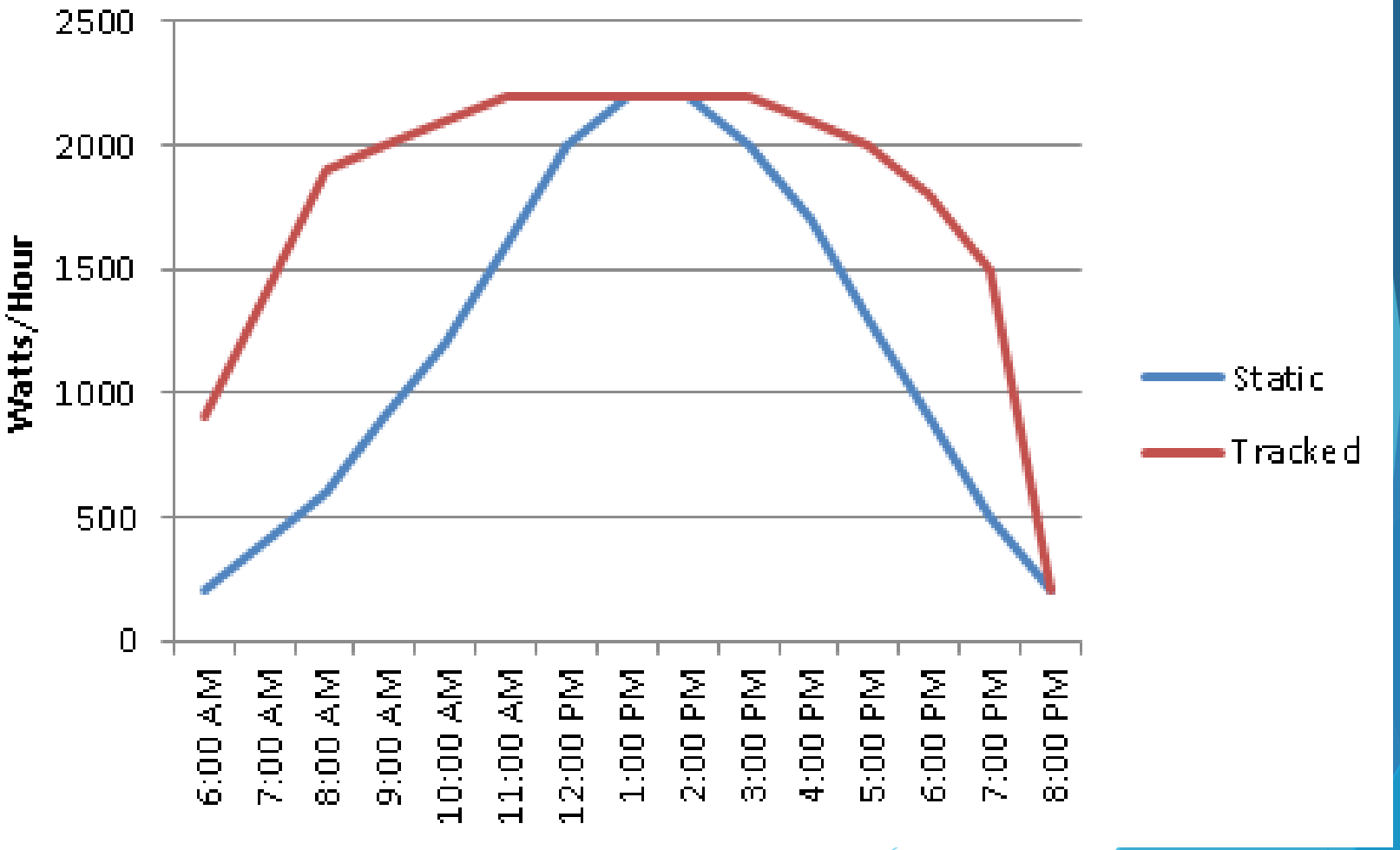
Typical U.S. Daily Electricity Demand



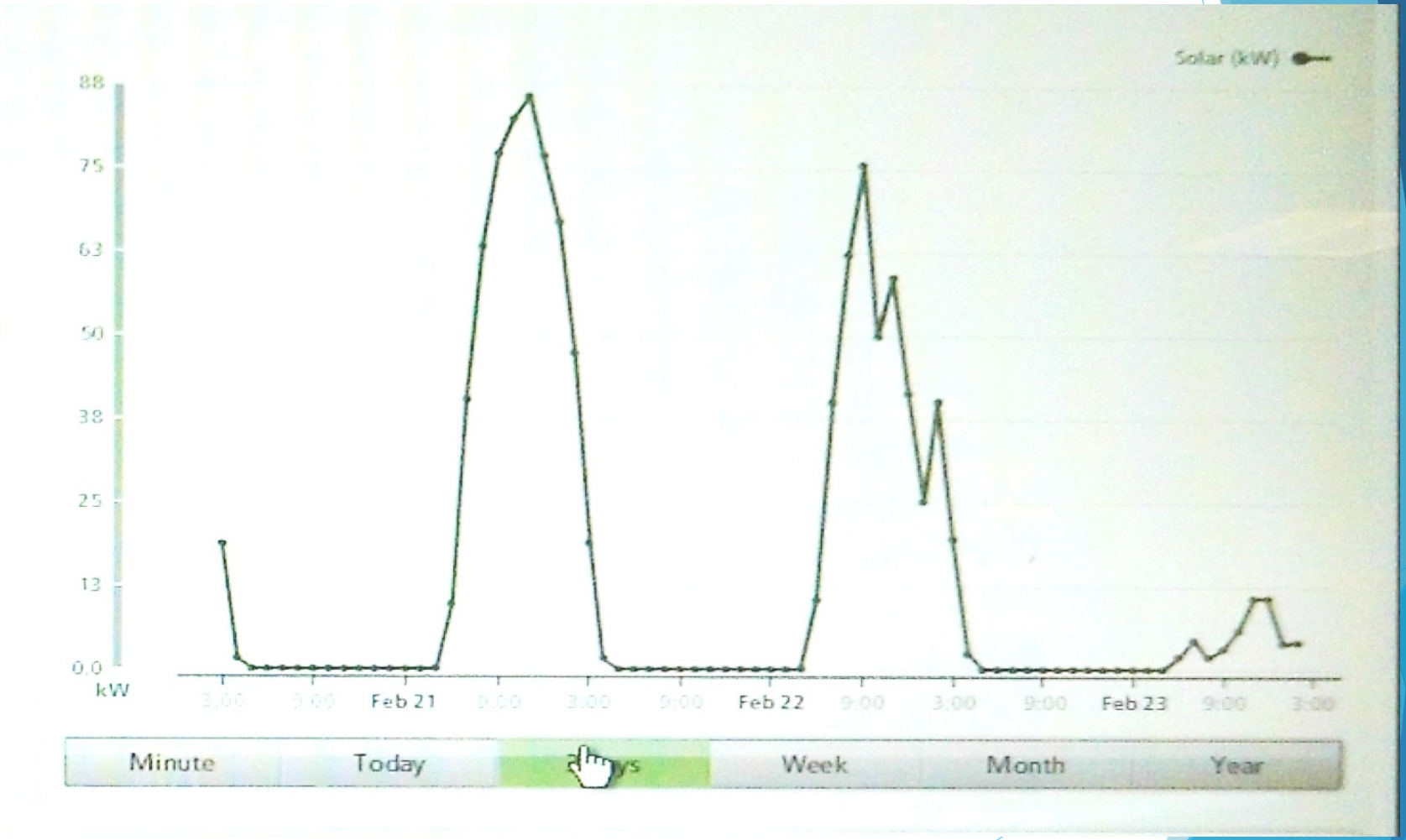
Typical California Daily Demand Load Profile



PV Panel Efficiency vs Time of Day



ABQ Jewish Community Center PV System Performance



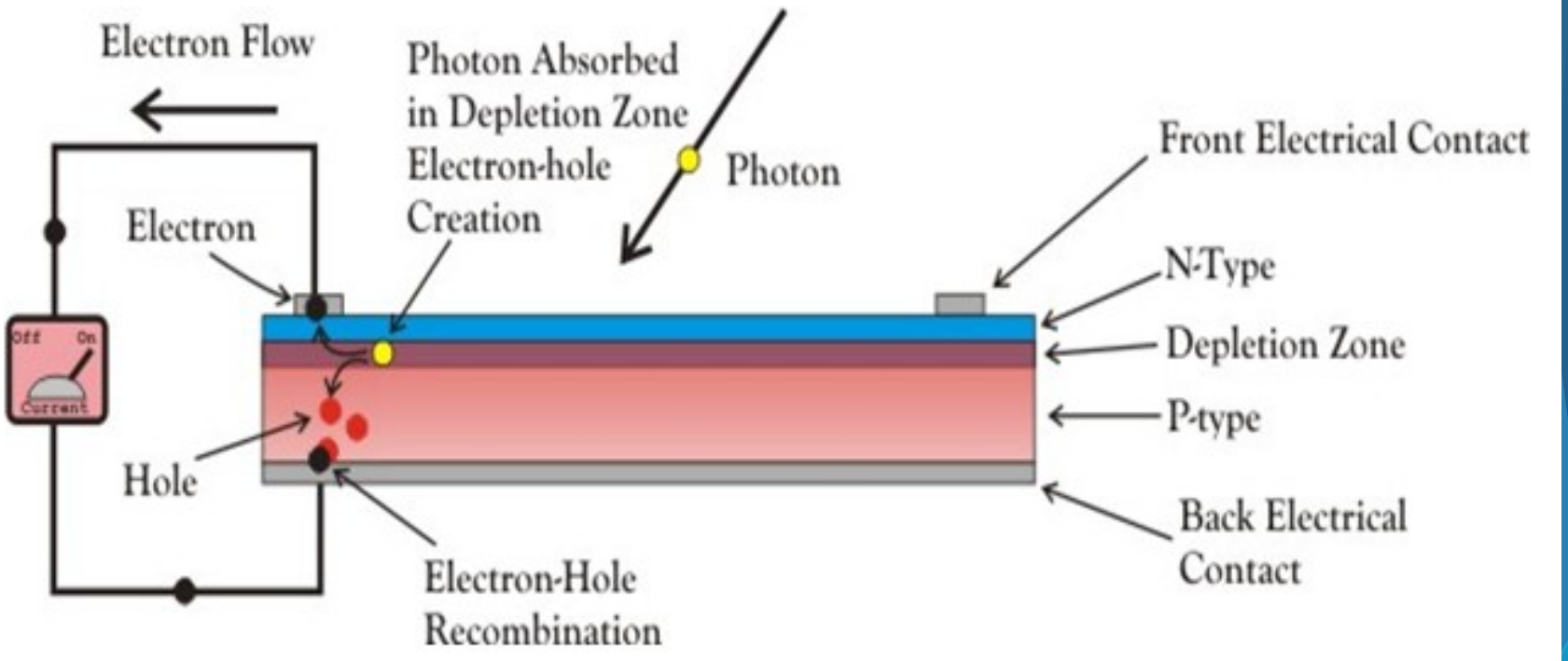
Conclusion

Nuclear energy best energy resource for generating baseload electricity

- Highest energy density of all energy resources (least amount of resource needed to produce electricity and least amount of life-cycle waste generated)
- Good energy resource utilization (good energy conversion efficiency for electricity generation)
- Excellent electricity-generating system reliability (highest system capacity factor)

Supplemental Slide

Photon Absorption in Solar Cell



PV Average Capacity Factor Can be Very Misleading (cont.)